BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: June 19, 1996

TO: R. Casey, S. Ozaki

FROM: M. S. Davis MSD

SUBJECT: Groundwater Impacts of RHIC Operations

I have reviewed the memo from D. Paquette and G. Schroeder to A.J. Stevens (June 4, 1996) and concur with their recommendations. Monitoring wells should be installed and a geomembrane placed over the beam dumps. The cost of monitoring well installation and the membrane should be covered by the facility. While the environmental impacts are minimal, the acceptance of RHIC operations by the community would be significantly enhanced by the implementation of these measures. It is important that we strive to reduce or eliminate our impacts on the environment as a goal for all of our operations.

Cc: S. Musolino
D. Paquette
G. Schroeder

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: June 4, 1996

TO: A. J. Stevens

FROM: D. Paquette/G. Schroeder Paquette GS

SUBJECT: Radioisotope Production Near RHIC Beam Dumps and Potential Groundwater Impact

Per your request, we have assessed the potential environmental impacts at the RHIC beam dump locations. The two beam dumps will be located at the 10 o'clock region of the RHIC Ring, and are approximately 450 feet apart. According to your memorandum of April 1, 1996, the vast majority (approximately 85%) of the beam injected into the RHIC is expected to end up at these target areas (see Attachments 1 and 2). Consequently, there is some concern that the direct activation of soils, soil moisture and groundwater may impact groundwater quality in areas surrounding the beam dumps.

Assessment of Radioisotope Production

In an effort to predict radionuclide production at the beam dump areas, your memorandum of April 1, 1996 outlined possible tritium and sodium-22 concentrations in: 1) soils directly outside the tunnel; 2) soils at the water table (approximately 16 feet below the tunnel floor); and 3) in areas near the Peconic River culvert that runs under the RHIC tunnel near one of the beam dumps (see Attachment 1). By converting the activation star production rate estimates into units of activity per unit volume, it appears that the generation of both tritium or sodium-22 will be quite small (Attachment 3). The maximum concentrations are 5.8 pCi/L for tritium and 7.3 pCi/L for sodium-22. The predicted concentrations for the RHIC beam dumps are significantly lower that those outlined in the AGS SAR. This is due to the RHIC facility's smaller duty cycle and lower beam intensity.

Assessment of Potential Impact to Groundwater

Based upon the concentrations presented above, the generation of tritium and sodium-22 in the soils and groundwaters surrounding the beam dumps will probably have a negligible impact to groundwater quality. Assuming that the predicted concentrations of tritium and sodium-22 at the beam dump areas are correct, the resulting increase in tritium concentrations above background levels (assuming 100 percent leaching) should only be approximately 6 pCi/L (or 0.3 percent of the NYS Drinking Water Standard of 20,000 pCi/L). Similarly, sodium-22 levels should only be approximately 7 pCi/L (or 1.7 percent of the DOE DCG of 400 pCi/L).

Based upon the groundwater flow pathways in the northeastern portion of BNL, any contaminants introduced at the RHIC beam dump areas will ultimately migrate toward BNL potable supply wells 10, 11, and 12 (Attachment 4). The distance between the beam dump areas and the closest supply well (Number 10) is approximately 4,800 feet. Assuming a groundwater flow rate of 0.75 feet per day (horizontal flow), tritium that enters the groundwater system at the beam dump area could reach the Potable Supply Well 10 area within 17 to 18 years. (Please note that tritium will migrate at the same rate as groundwater.) There are a number of complicating hydrologic factors affecting contaminant flow pathways, and these would best be evaluated using groundwater models. Factors such as downward vertical hydraulic gradients (which will cause the contaminants to migrate deeper into the Upper Glacial aquifer), and increased flow rates for groundwater within the zones of influence of the supply wells, will affect the migration rates. These radionulides will also be subject to natural decay and dilution before reaching the supply wells. Also, since the supply wells draw water from a large area, it would be expected that any contaminants would be further diluted as they are drawn into the wells. In the future, we might be want to utilize the Sitewide Groundwater Model that Geraghty and Miller, Inc. is presently constructing for the Office of Environmental Restoration. This would provide us with a better prediction of flow rates and concentrations over time.

Assessment of Potential Impact to Surface Water

The southern most RHIC beam dump is located approximately 125 feet north of the Peconic River culvert that runs underneath the RHIC ring. Based upon your calculations of April 1, 1996, direct tritium and sodium-22 production at the culvert will be negligible (i.e., at least six orders of magnitude less than the maximum concentrations presented above). Since the Peconic River is a groundwater fed stream, there is a slight chance that radionuclides leached from the soils surrounding the southern beam dump could make it into the river. However, as discussed above, the radionuclide concentrations in groundwater below the beam dumps are expected to be only slightly above background concentrations. Furthermore, based on the past five years of stream flow observations, there has been little to no flow in the Peconic River channel in the RHIC region. This has been primarily the result of low annual precipitation and the lowering of the water table by as much as seven feet in the RHIC region. Therefore, unless there was a substantial increase in yearly precipitation with a concurrent increase in river flow, there is little possibility of radionuclides generated at the beam dump to leave the site via a surface water pathway.

Recommendations for Further Actions

Based upon the predicted low level of radionuclide production at the two RHIC beam dump areas, there are no technical or regulatory reasons (based upon our understanding of DOE Orders) that would obligate RHIC to significantly alter or re-design the beam dumps. The latest DOE ALARA guidance with respect to radioactive material in groundwater is dose-driven at the point of reception. The calculated tritium and sodium-22 concentrations are far less than the respective DOE Order 5400.5 DCGs. Therefore, no additional engineering controls appear warranted from a cost/benefit standpoint. However, we would like to recommend that two issues be considered by the RHIC Department and the Directorate:

1. As a matter of verifying that the operations of the RHIC do not impact groundwater or surface water quality, we strongly recommend that BNL establish a routine groundwater monitoring program in both beam dump areas, and a routine surface water monitoirng program in one or two areas directly downstream of the Peconic River culvert. The groundwater monitoring program would require a minimum of four new monitoring wells (two wells located downgradient of each beam dump). Assessment of background radionuclide concentrations will be accomplished utilizing existing wells (e.g., Wells 17-

01, 17-02, and 17-03). The wells and Peconic River would be monitored by the S&EP Division initially twice per year for radionuclides (e.g., gross alpha, gross beta, gamma, and tritium). Preferably, the monitoring program would begin one year prior to the start-up of the RHIC in order to fulfill DOE pre-operational monitoring requirements. The costs associated with the installation of the wells should be factored into the RHIC projects budget. The S&EP Division's management will have to decide whether the costs associated with the annual groundwater and surface water sampling and analysis program should be back charged to the RHIC Department. The S&EP Division would provide RHIC with an estimate for costs associated with well installation and the sampling program.

2. Issues regarding the potential environmental impact of the RHIC project have been raised at a number of recent civic association meetings. In an effort to instill additional confidence in the RHIC project, the RHIC Department and the Directorate might wish to consider the construction of landfill-type caps (using geomembrane liners) over the two beam dump areas. The caps would prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby prevent the leaching of radionuclides to groundwater. Please note that a similar geomembrane cap was placed over the AGS Booster beam dump for the same purpose. The addition of caps over the beam dump areas would also allow for an increased margin of "safety" if beam intensities increase during the operational period of the RHIC. Since the RHIC Department is presently planning on adding two feet of additional soil cover over the beam dumps for shielding purposes, costs for this effort would be limited to engineering and geomembrane installation.

We look forward to working with you to ensure that the monitoring and groundwater protection issues are resolved. Please call us if you have any questions or additional concerns.

DCP/GS/rt

Attachments:
1. A.J. Stevens to D. Paquette Memorandum of March 1, 1996.
2. A.J. Stevens to D. Paquette Memorandum of May 1, 1996.
3. S&EP Radionuclide Calculations.
4. Water Table Map Showing Possible Contaminant Flow Pathways.
5. Topographic Map of the RHIC Beam Dump Areas and Position of the Peconic River

cc: W.R. Casey
M.S. Davis
H. Khanhauser
R. Miltenberger
J. Naidu
B. Royce
M.S. Rowe
T.Sperry
O. White

Division Head Concurrence

GW8120.96

Attachment 1

Brookhaven National Laboratory

MEMORANDUM

DETECTOR ~~RHIC~~ GROUP received 03-04-96

GW8020.96

copies: W. L. Casey
R. P. Mittenburger
B. Royce

Date: 03/01/96

To: Doug Paquette

From: A.J. Stevens AJS

Subj.: Radioisotope Production Near RHIC Dumps

This memorandum is intended to provide you with the "source term" for radioisotope production near the RHIC collider beam dumps. These dumps, located at the 10 o'clock insertion region, are the place where the vast majority (~85%) of beam injected into RHIC is expected to end up.[1] Ref [1] established a "safety envelope" of the equivalent of 8.9×10^{16} 100 GeV protons per year on each dump. This corresponds to 4 times the design intensity with operation for 38 weeks a year at 100% efficiency.

The dumps are about 450 ft. apart. According to the ground water map you provided the water table is at elevation 47.5 ft. at both of the dumps. The dump for the counter-clockwise ring is 125 ft upstream (measured from the beginning of the dump) of a culvert that passes underneath the ring. This special location will considered further below.

As I mentioned in our meeting on 02/28/96, we have to date assumed the criteria for ground water activation given in the AGS SAR. That criteria establishes a limit on the soil star density (basically spallation interactions per unit volume) production rate at any point in earth. The criteria is 1.5×10^{11} soil-stars cm^{-3} y^{-1}. In the model used in the AGS SAR, such a limit would correspond to 5×10^4 pCi per liter of ^{22}Na and 4.2×10^5 pCi per liter of ^{3}H. Ed Lessard informs me that the ^{22}Na activity concentration corresponds to DOE 5400.5 ALARA Design Guideline. [The corresponding guideline for ^{3}H is higher - 10^7 pCi per liter - and therefore less restrictive.] Please refer to the AGS SAR for the model of the local maximum activity concentration as well as a transport/dispersion equation which estimates the off-site concentration to be quite low.

I have run the CASIM program to determine the star density distribution around either of the RHIC dumps. At every R, the transverse distance from the beam line to some point in soil, the star density per proton (SD) has a maximum value which has a dependence on Z, the beam direction distance from the beginning of the dump. The following parameterization describes the calculations quite well:

$$(1) \qquad Z(\max) = 0.355 \times R + 3.175$$

$$(2) \qquad SD(\max) = \frac{1.7 \times 10^{-6}}{R^2} \times \exp(-D/\lambda_R)$$

In this geometry, R starts at 1.57m, the closest point in soil to the beam line, which is at 64 ft. elevation. D is the transverse distance in soil (D=0 at R=1.57m), and the attenuation length, λ_R, is .655m. At some (R,D), the maximum star density per proton will be given by (2) at a Z position given by (1).

The Z dependence before and after the maximum value is complicated, but the following parameterization is reasonably good (better than a factor of 2 over changes of 4 orders of magnitude and ignoring negative Z values which are quite low):

$$(3) \qquad SD = SD(\max) \times \exp\left(-\frac{(Z(\max) - Z)^{2.693}}{7.412}\right) \; for \; Z < Z(\max)$$

and

$$(4) \qquad SD = SD(\max) \times \{.95 \exp(-Z'/\lambda_1(Z)) + .05 \exp(-Z'/\lambda_2(Z)) \; for \; Z > Z(\max)$$

$$where \; Z' = Z(\max) - Z$$

$$with \; \lambda_1(Z') = \frac{1.75}{1 - \exp(-Z')} \; and$$

$$\lambda_2(Z') = \frac{3.82}{1 - \exp(-Z')}$$

The isotope production is 0.075 ^{3}H per star and 0.02 ^{22}Na per star.[2]

The remainder of this memorandum gives specific examples.

(1) Highest Concentration in Soil

The closest point to soil, as mentioned above, is R=1.57m, D=0. Here the SD (max) value is 6.9×10^{-7} stars/cc-p. Multiplying by the safety envelope value of 8.9×10^{16} protons, one obtains 6.1×10^{10} stars/cc-y, a factor of about 2.5 below the AGS SAR criteria. This gives maximum isotope concentrations of 4.6×10^9 ^{3}H atoms/cc-y and 1.2×10^9 ^{22}Na atoms/cc-y.

(2) Highest Concentration of Direct Production at Water Table Level

The water table is at 47.5 ft. and the soil begins at 64 ft., so the value of D (eqn.(2)) is 16.5 ft. or 5.03m. The R value is 1.57+5.03. Eqn (2) gives 1.8×10^{-11}. Again using the safety envelope number of protons gives 1.6×10^6 stars/cc-y, or 1.2×10^5 ^{3}H atoms/cc-y and 3.2×10^4 ^{22}Na atoms/cc-y. This is the maximum *direct* production, and does not include migration.

(3) **Direct Production at the Culvert**

The culvert is at about 49 ft. elevation, as near as I can tell from the aerial survey map. For this location, D = 4.57m, R = 6.14m, and Z = 38.1m. From Eqns. (2) and (1), SD (max) of 4.2×10^{-11} occurs at Z =5.35m. Eqn(4) gives a reduction of 9.45×10^{-6}, for a total of about 4×10^{-16} stars/cc-p which gives 71 stars/cc-y, or about 5.3 ^{3}H atoms/cc-y and 1.4 ^{22}Na atoms/cc-y.

Please let me know if you need any additional information or if anything in this memorandum is not clear.

References/Footnotes

1. M. Harrison and A.J. Stevens, "Beam Loss Scenario in RHIC," AD/RHIC/RD-52, Jan., 1993.

2. J.D. Cossairt, "Review of the Abort Dump Shown in the SSC Conceptual Design Report," FNAL TM-1460, April, 1987.

3. The distance chosen is immediately below the floor of the tunnel enclosure. As it happens, the same star density (albeit at a somewhat greater transverse distance) is obtained in the opposite direction, i.e., in the earth immediately above the tunnel enclosure.

cc:

E. Lessard
S. Musolino
G. Schroeder

Attachment 2

Brookhaven National Laboratory

MEMORANDUM

DETECTOR RHIC GROUP

05-02-96

GW802096

Date: 05/01/96

To: Doug Paquette

From: A.J. Stevens ajs

Subj.: Beam Dump Locations

The RHIC beam dumps will be located at the 10 o'clock insertion region. They begin about 220 ft. downstream of the crossing point in each direction and are 17 ft. in length.

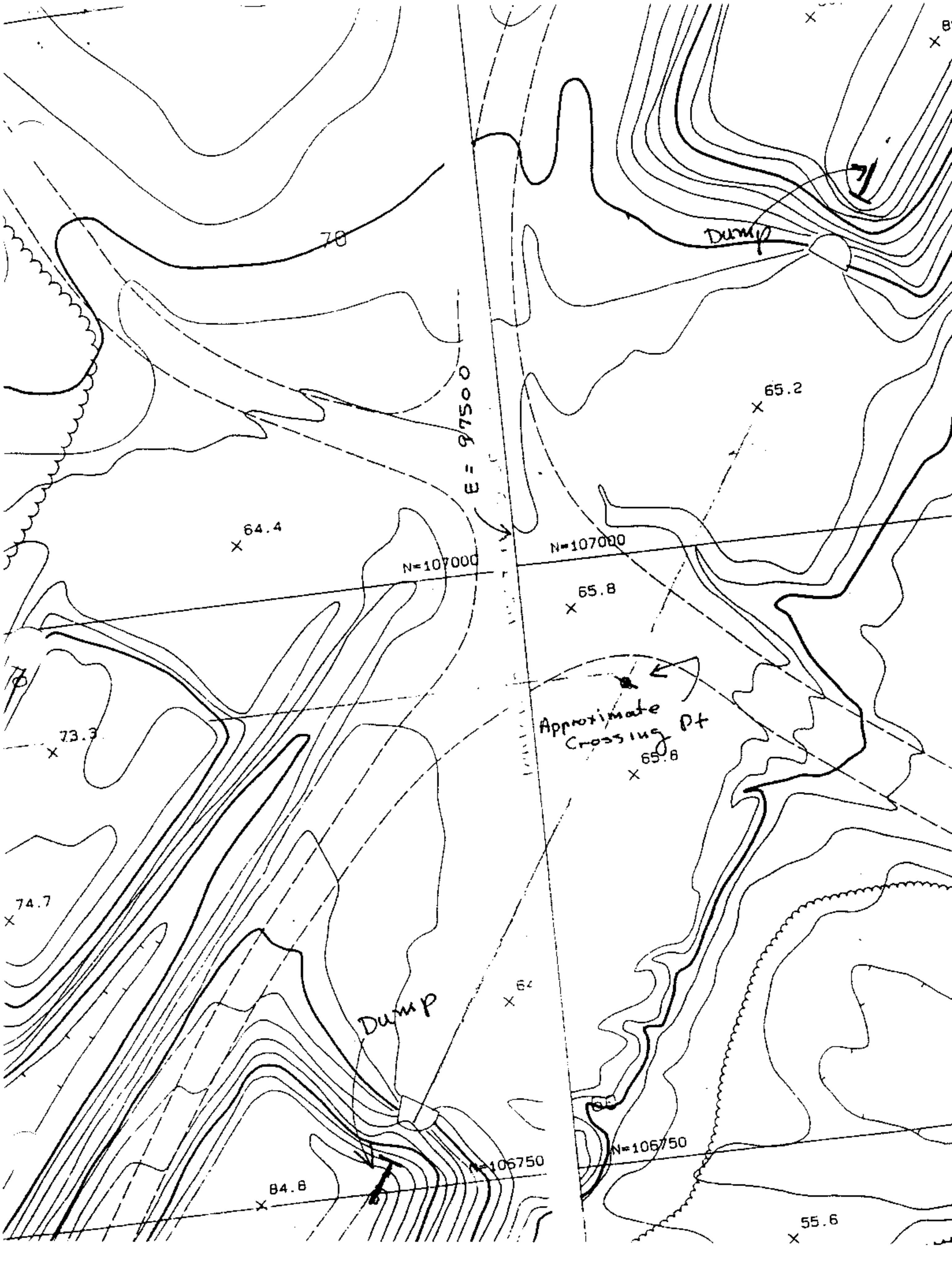
The attachment shows the approximate locations on a Xerox copy of a part of the aerial survey made in April 1991. The scale is 1 inch to 50 ft. I have done the best job I can of showing the dump locations on this map. I would guess that the locations indicated are good to 15 ft. or so if you measure from the grid coordinates shown. My own measurements (on the "original") give:

Dump	End	Coordinates (N,E)
Counter-clockwise Beam	Upstream	(106762,97422)
Counter-clockwise Beam	Downstream	(106747,97413)
Clockwise Beam	Upstream	(107134,97655)
Clockwise Beam	Downstream	(107149,97664)

If this accuracy is not sufficient for your needs at this time, we will have to consult the survey group. Please let me know if this is necessary.

Attachment

cc: E. Rodger
S. Musolino



70
Dump
65.2
E = 97500
64.4
N=107000
N=107000
65.8
Approximate Crossing Pt
65.8
73.3
74.7
Dump
N=106750
N=106750
84.8
55.6

From A. Steven's memo of 3/1/96,

Highest concentration, direct production @ water table:

- $^3H = 1.2E5$ atoms $cc^{-1}\,yr^{-1}$

$$\lambda(^3H) = \frac{\ln 2}{12.3\ yr} = 1.79E{-9}\ sec^{-1}$$

$$A = \lambda N$$

$$A = 1.79E{-9}\ Bq\ (1.2E5\ cc^{-1}\,yr^{-1})$$

$$A = 2.15E{-4}\ \frac{Bq}{cc\text{-}yr}\left(\frac{Ci}{3.7E10\ Bq}\right)\left(\frac{10^{12}\ pCi}{Ci}\right)$$

$$A = 0.0058\ \frac{pCi}{cc}\left(\frac{cc}{ml}\right)\left(\frac{10^3\ ml}{l}\right)$$

$$\boxed{A = 5.8\ \frac{pCi}{l}}$$

- $^{22}Na = 3.2E4$ atoms $cc^{-1}\,yr^{-1}$

$$A = \lambda N = 8.45E{-9}\ Bq\ (3.2E4\ \text{atoms}\ cc^{-1}\,yr^{-1})$$

$$A = 2.7E{-4}\ \frac{Bq}{cc\text{-}yr} = 0.0073\ \frac{pCi}{cc}$$

$$\boxed{A = 7.3\ \frac{pCi}{l}}$$

DOE Order 5400.5 DCGs: $^3H = 2E6$ pCi/l, $^{22}Na = 10,000$ pCi/l

Drinking H_2O standard, or 4% DCG: $^3H = 80,000$ pCi/l

$^{22}Na = 400$ pCi/l

Highest radionuclide concentration in soil:

$$N(^3H) = 4.6E9 \text{ atoms cc}^{-1} \text{ yr}^{-1}$$

$$A = \lambda N$$
$$= 1.79E{-9} \text{ Bq } (4.6E9 \text{ atm cc}^{-1} \text{ yr}^{-1})$$
$$= 8.23 \frac{\text{Bq}}{\text{cc-yr}} \left(\frac{\text{Ci}}{3.7E10 \text{ Bq}}\right)\left(\frac{10^{12} \text{ pCi}}{\text{Ci}}\right)$$

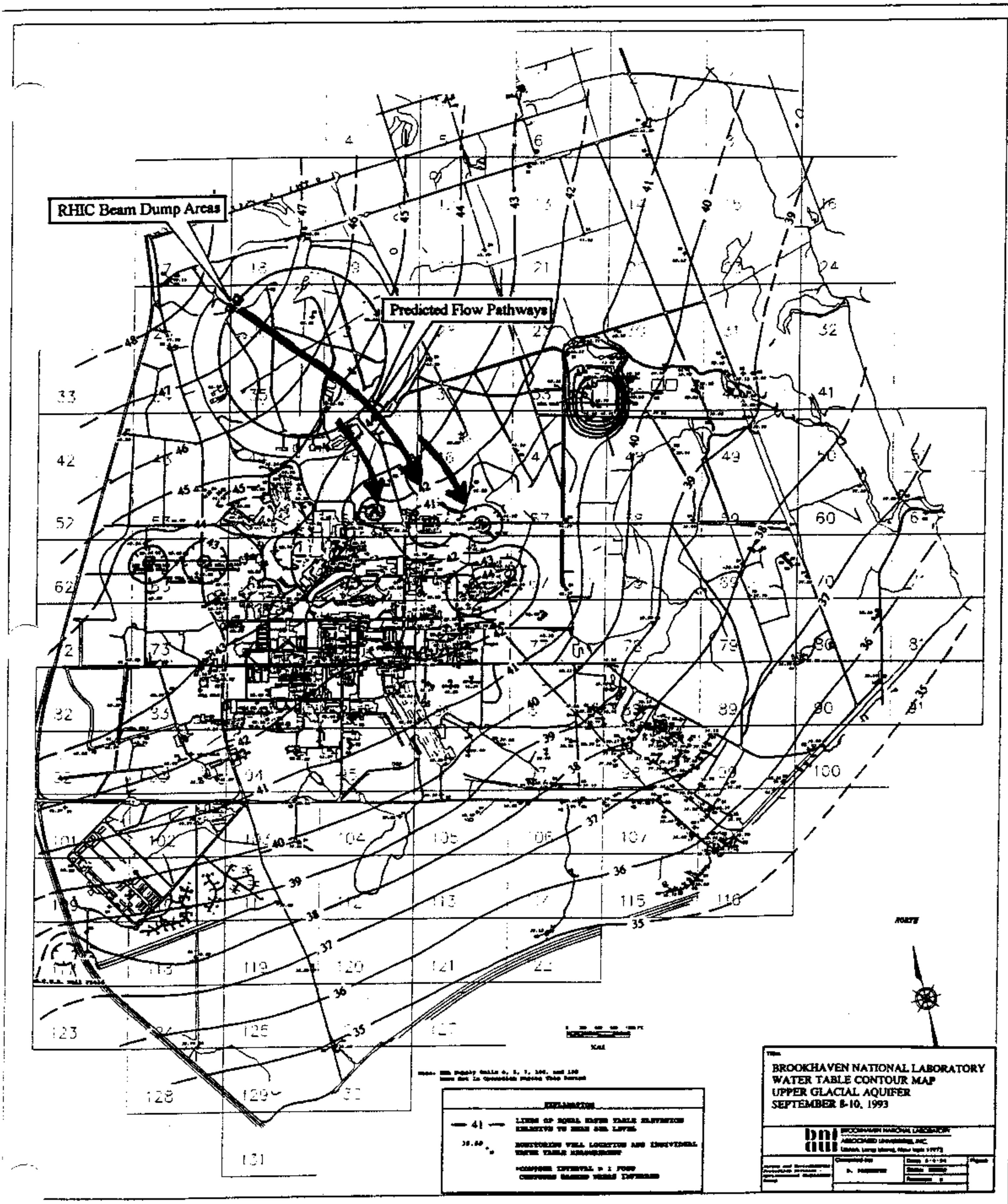
$$\boxed{A_{soil} = 222.4 \text{ pCi cc}^{-1} \text{ yr}^{-1}}$$

$$N(^{22}Na) = 1.2E9 \text{ atom cc}^{-1} \text{ yr}^{-1}$$

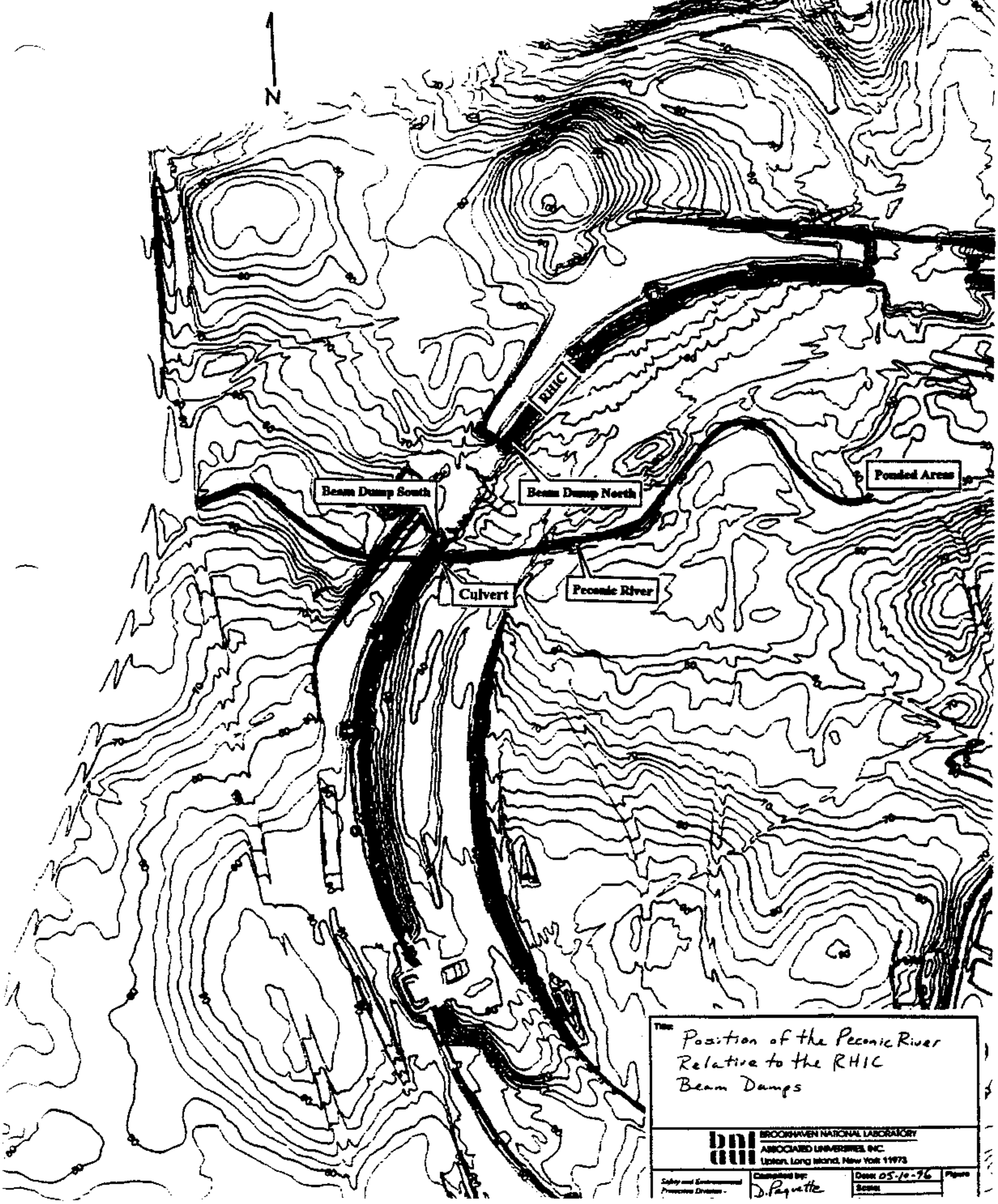
$$A = 8.45E{-9} \text{ Bq } (1.2E9 \text{ atom cc}^{-1} \text{ yr}^{-1})$$
$$= 10.1 \text{ Bq cc}^{-1} \text{ yr}^{-1}$$

$$\boxed{A_{soil} = 274 \text{ pCi cc}^{-1} \text{ yr}^{-1}}$$

Attachment 4



Attachment 5



BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

Date: December 1, 1998

To: Distribution

From: G. Schroeder GS

Subject: RHIC Preoperational Monitoring Plan

Pursuant to DOE Order 5400.1, a Preoperational Monitoring Plan for the RHIC facility has been compiled. This Plan establishes the rationale for the proposed sampling and specifies media to be sampled, analyses to be employed and sample frequency. Due to the proximity of the anticipated start-up of RHIC in May, 1999, it is important that the sampling events outlined in the Plan be incorporated into the Field Team sampling schedule as soon as possible to establish a valid preoperational baseline. (Note that this version of the Plan incorporates comments received on the draft Plan that was circulated in August.) If you have any comments or questions regarding the contents of the Plan, please contact me at Ext. 7045.

GS:rt
Attachment

Distribution:

E. A. Flores
R. Lee
S. Musolino
D. Paquette

EM0220.98

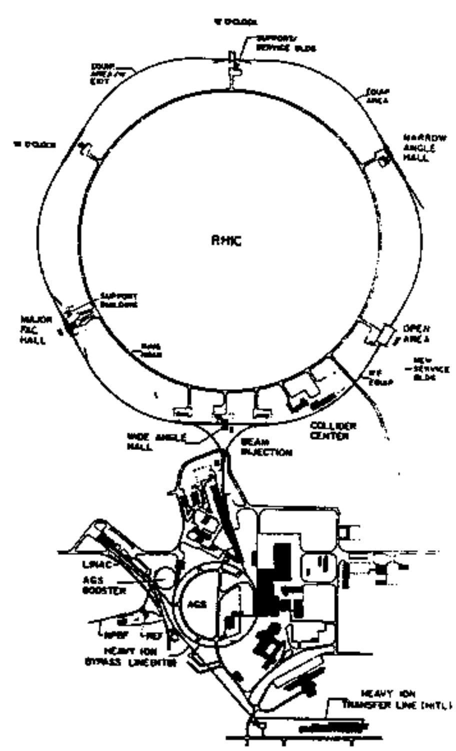
RHIC Preoperational Monitoring Plan

DOE Order 5400.1, "General Environmental Radiation Protection Program", requires that a Preopeartional Assessment be conducted for any new facility that has the potential for environmental impact. Since the Relativistic Heavy Ion Collider (RHIC) is expected to come on line in the second quarter of CY 1999, the BNL environmental monitoring program will be expanded to include the collection of samples which will provide data for such an assessment. Considerations for the size of the program and the types of samples to be collected are provided below.

Background

The RHIC facility will operate to study nuclear phenomena in heavy ion collisions. It will collide two ion beams circulating in opposite directions via a pair of superconducting magnet rings in a 3.8 kilometer circumference tunnel (Fig. 1). Ions or protons will be extracted from the AGS where they will be inserted into the rings and accelerated to full energy. At the end of the useful life of the beams, the particles are directed to a shielded beam stop and the cycle is repeated. Beam stops are located at the 10 o'clock position of the ring and at the Transfer Line where the X and Y-lines split from the W-line (see Fig. 2). Potential public dose from the facility is expected to be less than 1 mrem per year in both routine and abnormal beam loss scenarios[1].

Figure 1 RHIC schematic.



Soil Sampling

Because the RHIC utilizes superconducting magnets which can tolerate only very small amounts of energy deposition from beam losses, such losses have been necessarily minimized as part of the accelerator's design. Consequently, no significant secondary radiation, of the type which could create soil activation outside of the beam tunnel is expected. Two exceptions to this general rule are facility beam collimators and stops. The primary area which will experience low-level soil activation as part of routine operations will be at the beam stops located on either side of the 10 o'clock position. The second area of anticipated soil activation is near the collimators located on either side of

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[1] RHIC Safety Assessment Document, November 1998.

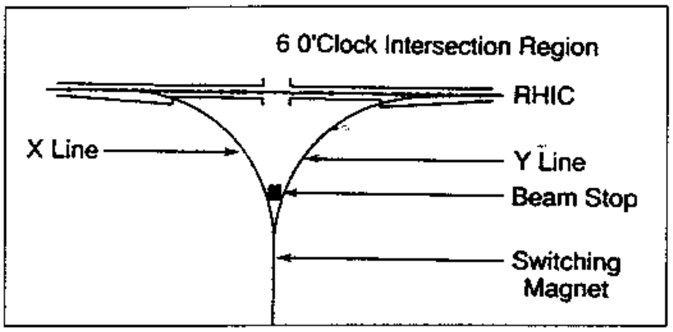

Figure 2 Location of Transfer Line beam stop.

the 8 o'clock position. Tritium and ^{22}Na are the radionuclides which will be of practical concern. Other radionuclides which might be produced are miniscule in quantity or of a very short half-life.

As part of a preoperational survey to determine the environmental impacts associated with RHIC operations, soil samples will be collected from the soil berms above the beam stop and collimator prior to and following operations. Soil sampling will be coordinated with well installation to provide easy access to subsurface soils. These samples will be submitted for gamma spectroscopy analysis which will be sensitive to any ^{22}Na produced by RHIC operations.

Groundwater Sampling

It is expected that soil activation will occur in the sand above and below the 10 o'clock beam stops and the 8 o'clock collimators as part of routine operations. (Note that the Transfer Line beam stop will receive much lower GeV/yr, and activation potentials around this stop are considered minimal by comparison.) Tritium and ^{22}Na will be the two principal radionuclides produced. Though water concentrations close to the beam stop will be higher, concentrations at the water table are expected to be less than 10 pCi/L for each isotope[2]. In an effort to ensure minimal transfer of radionuclides from soil to groundwater, a geomembrane liner will be installed over the beam stops (see Fig. 3). This will prevent precipitation from leaching radionuclides from soil to groundwater.

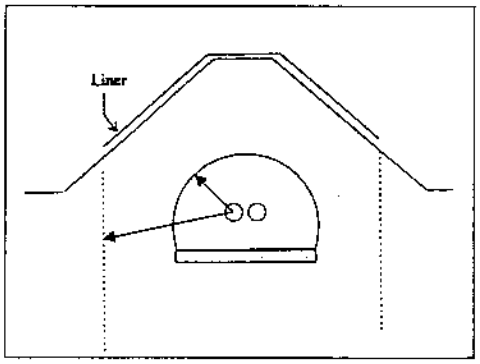

Figure 3 Liner/tunnel cross section.

Though no groundwater impact is expected from RHIC operations, groundwater monitoring will be conducted downgradient of the anticipated activation areas. Groundwater samples will be obtained from twelve permanent monitoring wells. Six wells will be located at the 8 o'clock position, and

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[2] D. Paquette and G. Schroeder to A.J. Stevens, June 4, 1996.

six at the 10 o'clock position (see Table 1 and Figure 4). Samples will be analyzed for radiological parameters including gross activity, gamma-emitting radionuclides, and tritium. Background water quality will be determined based on samples collected from existing wells located in Grid 017 (wells 017–01 through –04, see Figure 4).

Table 1 Proposed RHIC Groundwater Monitoring Well Locations

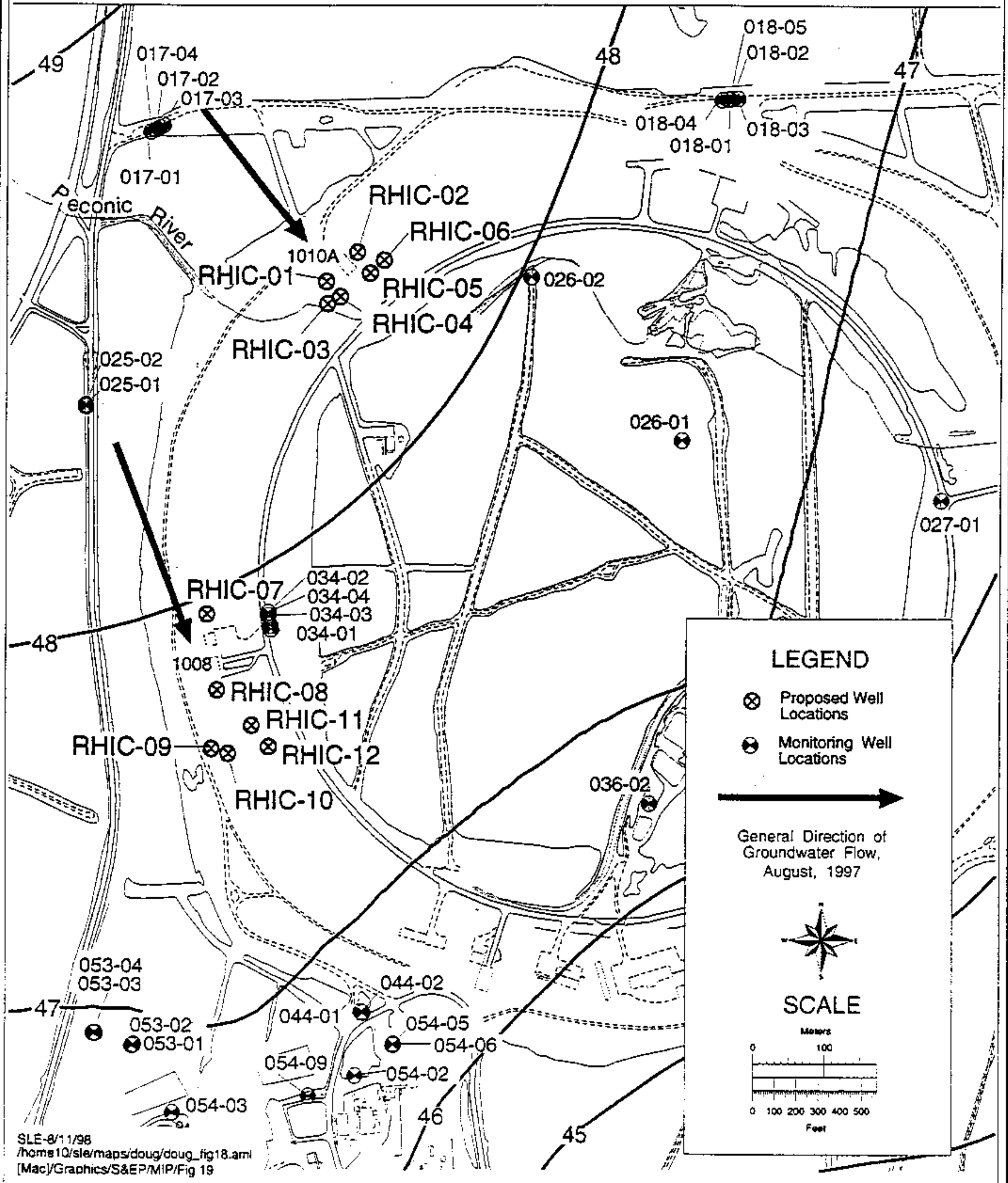
Region	*Well ID*	*Location*
10 o'clock	RHIC-01	Beam stop west of crossing point, w/in 15 ft. of tunnel.
	RHIC-02	Beam stop east of crossing point, w/in 15 ft. of tunnel.
	RHIC-03	South of west beam stop.
	RHIC-04	South of west beam stop.
	RHIC-05	South of east beam stop.
	RHIC-06	South of east beam stop.
8 o'clock	RHIC-07	North of 8 o'clock crossing pt., near collimator face, w/in 15 ft. of tunnel.
	RHIC-08	South of 8 o'clock crossing pt., near collimator face, w/in 15 ft. of tunnel.
	RHIC-09	West of RHIC tunnel, w/in 25 ft. and south of cap.
	RHIC-10	West of RHIC tunnel, w/in 25 ft. and south of cap.
	RHIC-11	East of RHIC tunnel, w/in 25 ft. and south of cap.
	RHIC-12	East of RHIC tunnel, w/in 25 ft. and south of cap.

Surface Water and Sediment Sampling

The southern 10 o'clock beam stop is located approximately 125 feet north of the Peconic River culvert that runs beneath the RHIC tunnel. Based upon calculations, the potential for direct activation of water running in the culvert is negligible[3]. Since the Peconic River is a groundwater fed body, there is a small potential for radionuclides below the southern 10 o'clock region to be leached upward into the riverbed as levels rise. Due to the small radionuclide concentrations predicted in this region, such leaching, if it occurs, would not be environmentally significant. However, this will be verified by direct measurement of

[3] A. J. Stevens to D. Paquette, March 1, 1996.

Figure 4 Proposed Groundwater Monitoring Wells for the RHIC Facility



surface water and sediments in the immediate area. Surface water samples will be collected before and following continuous beam operations to determine what impacts, if any, have occurred. Note that flow at the Peconic culvert exists at the time of this writing, though this condition has been rare for several years due to persistent low water table levels. Water samples will be submitted for gross activity, tritium and gamma spectroscopy analyses, while sediment will be analyzed by gamma spectroscopy only.

External Exposure Monitoring

Prompt radiation external to the RHIC tunnel will be generated by facility operations. The radiation field will consist mainly of neutron, gamma and muon radiation. The beam stops are expected to account for 85% of the total loss of beam energy. Therefore, maximum exposure fields will occur in this region. Calculations have been performed by Stevens which indicate that without additional earth shielding, the annual effective dose equivalent due to skyshine at the site boundary nearest the 10 o'clock region (near the north guard gate) is 6.5 mrem/yr[4]. Note that this assumes several conservative assumptions such as four times design beam intensity, an occupancy factor of unity, etc. However, an additional 4.5 feet of sand is to be added to the beam stop berm, reducing the dose at the north gate area to less than 1 mrem/yr.

One of the recommended methods for conducting direct radiation measurements at high energy accelerator facilities includes the use of integrating devices such as thermoluminescent dosimeters (TLDs)[5]. Existing *in situ* monitoring includes TLDs at monitoring station P2, located at the northwest corner of the site, within 500 feet of the RHIC 11 o'clock position and at station 034-400, near the 8 o'clock position. TLDs at these locations are exposed for one calendar quarter and are exchanged four times per year. To augment the ability to calculate potential off-site dose equivalents due to skyshine, it is proposed that a total of four new TLDs be located on the berms over the beam stop and collimator areas (see Figure 5).

While TLDs will be useful in assessing gamma radiation external to the RHIC, essentially all potential dose associated with facility operations will be due to neutron radiation. CR-39 track-etch neutron dosimeters of the same type used to monitor personnel exposure at the Alternating Gradient Synchrotron are proposed to assess this exposure. RHIC personnel have located TLD and CR-39 neutron dosimeters at six locations within facility service buildings. The anticipated neutron spectrum is such that building materials will attenuate little, if any, of the neutron field. These units will, therefore, be valuable in assessing potential off-site neutron doses as well. It is proposed that additional CR-39 dosimeters be placed at the same locations as the beam stop and collimator berm TLDs. Additonally, CR-39 dosimeters will be placed at stations P2 and 034-400.

It is noted that are many difficulties inherent in neutron dosimetry, particularly when the energy spectrum has not been definitively established. Other factors to be considered are the equivalency of the calibration source energy spectrum and that of the expected neutron field, as well as the energy sensitivities of the dosimeter. Considering these

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[4] A.J. Stevens to Distribution, June 11, 1996.

[5] DOE/EH-0173T, "Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance", January 1991, U.S.D.O.E.

factors, use of the CR-39 dosimeters for this purpose is reasonable. In any event, projected neutron skyshine doses are in the 1 mrem/yr range, far too small to be observed using current dosimeter technologies. While the proposed dosimeters are unlikely to register the small external radiation fields generated by RHIC operations, they will provide confirmation that no regulatory public dose limits have been exceeded.

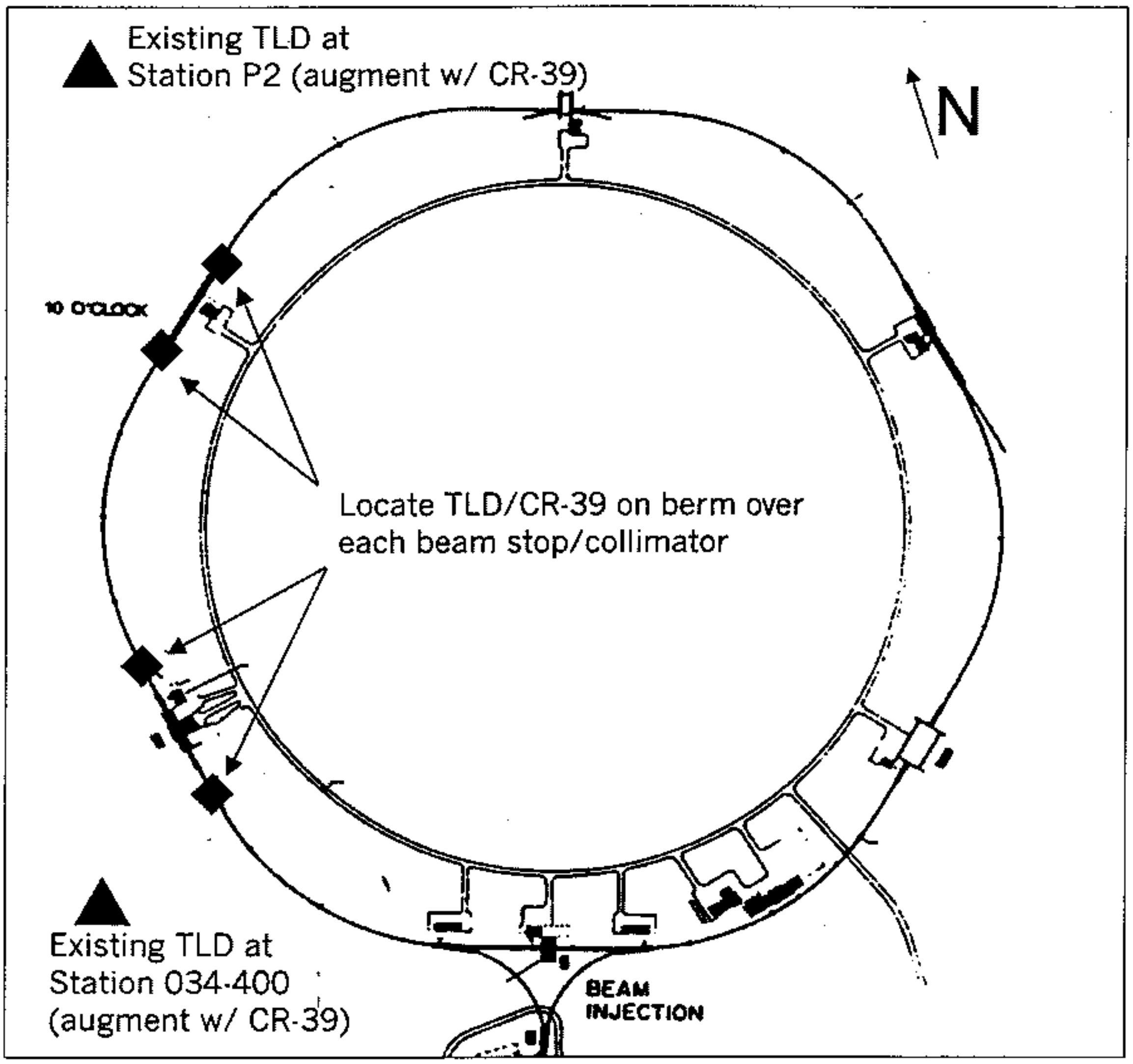

Figure 5 Existing and proposed RHIC environmental dosimeter stations.

Table 2 RHIC Environmental Sample Frequency

Media / Sample Type	*Analysis*	*Collection Frequency*
Soil	Gamma spectroscopy	Preoperational samples to be coordinated with well installation schedule.
Groundwater	Tritium	Quarterly
	Gamma spectroscopy	Quarterly
	Gross Activity	Once annually
	Metals	Twice annually
Surface Water	Tritium	Twice annually (as flow allows)
	Gamma spectroscopy	Twice annually (as flow allows)
	Gross Activity	Once annually (as flow allows)
Sediment	Gamma spectroscopy	Once annually
Dosimeters	Gamma and neutron	Quarterly

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: October 8, 1998

TO: S. Musolino

FROM: D. Paquette

SUBJECT: **RHIC Groundwater Impact Assessment**

Attached, please find the report titled "Brookhaven National Laboratory, Relativistic Heavy Ion Collider - Potential Impacts to Groundwater Quality." This summary report was excerpted from the recently distributed "BNL Groundwater Monitoring Improvements Plan for FY 1998 and FY 1999 (September 23, 1998)." I would like to recommend that this report be inserted into Appendix 21 of the RHIC Safety Analysis Document.

If you have any questions, please call me at extension 7046.

Attachment

cc: S. Hoey
R. Lee
GW8020.98

Brookhaven National Laboratory
Relativistic Heavy Ion Collider

Potential Impacts to Groundwater Quality

Prepared by:
Douglas E. Paquette, PG
Hydrogeologist
Environment, Safety and Health Services Division

October 8, 1998

Brookhaven National Laboratory is Operated by Brookhaven Science Associates for the US Department of Energy

Brookhaven National Laboratory
Relativistic Heavy Ion Collider - Potential Impacts to Groundwater Quality

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1.0 Introduction

The Relativistic Heavy Ion Collider (RHIC) is designed to study nuclear phenomena in heavy ion collisions. The Collider consists of two beams circulating in opposite directions around a pair of superconducting magnet rings in a 3.8 kilometer circumference tunnel. The machine is designed to collide the beams at six locations where experiments can be carried out. Beam line interaction with the RHIC collimators and beam stops will produce secondary particles that may interact with the soils that surround 8 o'clock and 10 o'clock portions of the RHIC tunnel. These interactions will likely result in the production of tritium and sodium-22 in the soils. Because the BNL site is located over an EPA designated sole-source aquifer system, an analysis of the potential impact to groundwater quality is provided below.

2.0 General Hydrogeology of the BNL Site and Groundwater Quality

The BNL site is underlain by approximately 1,300 feet of unconsolidated Pleistocene and Cretaceous sediments overlying Precambrian bedrock (Table 1). The unconsolidated sediments, subdivided from youngest to oldest, are as follows:

- Upper Pleistocene deposits (Upper Glacial aquifer),
- Gardiners Clay (confining unit),
- Magothy Formation (Magothy aquifer), and
- Raritan Formation (Raritan Clay confining unit and Lloyd aquifer)

A description of the geologic and hydraulic properties of the Upper Pleistocene deposits are provided below. New monitoring wells required for improved facility monitoring under this Groundwater Monitoring Improvements Plan will installed within the shallow sections of the Upper Glacial aquifer. Detailed discussions on Gardiners Clay, Magothy and Raritan formations can be found in deLaguna (1963), Faust, 1963, Warren *et al.* (1968), and the BNL Regional Groundwater Model Report (Geraghty and Miller, 1996). A generalized hydrogeologic cross section for the BNL site is presented in Figure 1.

2.1 Upper Pleistocene (Glacial) Deposits

The Upper Pleistocene deposits on Long Island were deposited during two Wisconsin glaciation events (Lubke, 1964). At BNL, the glacial deposits range from 130 to 200 feet in thickness, and can be divided into three distinctive units. From oldest to youngest, the units are: the basal "Unidentified Unit"; sand and gravel outwash and moraine deposits; and near surface silt and clay deposits.

<u>Basal Unidentified Unit</u>: The basal "Unidentified Unit" (first described by deLaguna, 1963), is between 25 to 50 feet thick, and appears to be restricted to the central and southern portions of the site. This unit is characterized by light green, fine to medium-

grained sand and sandy clay (with 5 to 10% glauconitic clay). The Unidentified Unit is generally less permeable than the overlying coarse-grained glacial moraine and outwash deposits.

Outwash and Moraine Deposits: The Upper Pleistocene deposits at BNL primarily consist of 130 to 200 feet of broadly stratified glacio-fluvial outwash deposits composed of silica-rich medium to coarse-grained sand and gravel. Thin layers of silt and clay have been observed within the outwash deposits, but do not represent significant barriers to groundwater flow. Along the southwest border of BNL, the Ronkonkoma terminal moraine is recognized as a series of discontinuous hills which reach a maximum elevation of 130 feet above sea level (Figure 2).

Near Surface Silt and Clay: Near surface silt and clay deposits are located along the lowlands of the Peconic River watershed. Although the full areal extent of these deposits has not been determined, their presence is inferred beneath marshes and areas of ponded water, which are wide-spread in the eastern portion of the site (see Warren *et al.*, 1968). Recent drilling within the BNL Sewage Treatment Plant (STP) area and the Relativistic Heavy Ion Collider (RHIC) area has revealed that fine sand, silt and clay deposits occur within 30 feet of land surface. These low permeability deposits retard groundwater recharge, and are responsible for creating perched or semi-perched water table conditions. In the STP area, a broad groundwater mound has formed below the plant's filter beds, where it is estimated that up to 0.1 MGD of STP effluent is recharged directly to Upper Glacial aquifer.

2.2 Upper Glacial Aquifer

The Upper Glacial aquifer is widely used on Long Island for both private and public water supply. Drinking water and process water supplies at BNL are obtained exclusively from the Upper Glacial aquifer. The Laboratory currently operates six potable water supply wells that can be pumped at rates of 1,200 gpm, and five process supply wells that can be pumped at rates between 50 and 1,200 gpm. During maximum water usage at BNL, up to 6 MGD are pumped from the Upper Glacial aquifer. Most of this water is returned to the aquifer by way of recharge basins or discharge of STP effluent to the Peconic River. Groundwater in the Upper Glacial aquifer beneath BNL generally exists under unconfined conditions. However, in the areas along the Peconic River where low permeability near surface silt and clay deposits exist, semi-confined conditions may occur. Depth to groundwater varies from several feet below land surface within the lowlands near the Peconic River, to as much as 75 feet in the higher elevation areas located in the central and western portions of the site.

A main east-west trending regional groundwater divide is located approximately 0.5 miles north of BNL (Figure 3). A second groundwater divide, which transects portions of the BNL site during periods of high water table position (i.e., during periods of inflow from the aquifer to the stream bed), defines the southern boundary of the area contributing groundwater to the Peconic River watershed (Scorca *et al.*, 1996, Scorca *et al.*, 1997). Shallow groundwater flow directions across the BNL site are influenced by natural drainage systems, varying between being eastward along the Peconic River, southeastward toward the Forge River, and southward toward the Carmans River (Figures 3, 4 and 5). Additionally, pumping and recharge induced stresses on the aquifer system are considerable in the central area of the site. Due to variable supply well pumping schedules and rates, considerable variations in groundwater flow directions and velocities occur (compare Figures 4 and 5). Groundwater flow directions in the southwest corner of the site are also influenced by pumpage at the Suffolk County Water Authority well field located on the west side of the William Floyd Parkway.

Aquifer pumping tests conducted at BNL indicate that the horizontal hydraulic conductivity of the Upper Glacial aquifer is approximately 1,300 gpd/ft^2 (or 175 ft/d based upon an aquifer thickness of 145 feet) and a specific yield (effective porosity) of 0.24 (Warren *et al.*, 1968; H2M/Roux Associates, 1985; CDM, 1995; P.W. Grosser, P.C., 1997). Total porosity value for the Upper Glacial is estimated to be 0.33 (Warren *et al.*, 1968). Data from aquifer pumping tests and infiltration tests conducted at BNL by the USGS indicate that the vertical to horizontal anisotropy within the Upper Glacial aquifer is between 1:4 to 1:18 (Warren *et al.*, 1968). The average vertical to horizontal anisotropy within the Upper Glacial aquifer on Long Island has been estimated to be 1:10 (Smolensky *et al.*, 1989). The hydraulic properties of the basal Unidentified Unit cannot be determined with any degree of certainty using the current well network. Since the Unidentified Unit contains significant clay and silt, it is expected that these deposits are less permeable than the overlying glacial outwash and morainal sand and gravel.

The horizontal hydraulic gradient at BNL is typically 0.001 feet per foot (ft/ft). However, in recharge and pumping areas, the hydraulic gradient can steepen to 0.0024 ft/ft or greater. In most areas of the site, the natural groundwater flow velocity is estimated to be approximately 0.75 feet per day (ft/d). However, flow velocities in recharge areas may be as high as 1.45 ft/d, while velocities up to 28 ft/d have been calculated for areas near BNL potable and process supply wells (Woodward-Clyde Consultants, 1993). Water-level measurements taken from paired water table and deep Upper Glacial wells located along the northern site boundary (near the regional groundwater divide) indicate significant deep-flow recharge conditions, with downward vertical hydraulic gradients of up to 0.006 ft/ft. Head differences become negligible in paired wells located in the central and southern areas of the site, indicating that groundwater flow within the Upper Glacial aquifer is predominantly horizontal in these areas. The BNL site is, however, located within a SCDHS designated deep-flow recharge area (Hydrogeologic Zone III) for the Magothy and Lloyd aquifers (Koppleman, 1978; SCDHS, 1987). Comparison of water level measurements from Glacial aquifer and Magothy aquifer wells indicate significant downward flow across the BNL site (BNL, 1998).

2.3 Groundwater Quality and Classification

In Nassau and Suffolk Counties of Long Island, New York, drinking water supplies are obtained exclusively from groundwater aquifers (e.g., the Upper Glacial aquifer, the Magothy aquifer, and to a limited extent the Lloyd aquifer). The Long Island aquifer system has been designated by the U.S. EPA as a Sole Source Aquifer System, pursuant to Section 1424(e) of the Safe Drinking Water Act. Groundwater in the sole source aquifers underlying the BNL site is classified as "Class GA Fresh Groundwater" by the State of New York (6NYCRR Parts 700-705). The best usage of Class GA groundwater is as a source of potable water supply. As such, federal drinking water standards, NYS Drinking Water Standards (NYS DWS), and NYS Ambient Water Quality Standards (NYS AWQS) for Class GA groundwater are used as groundwater protection and remediation goals.

For drinking water supplies, the federal maximum contaminant levels (MCLs) set forth in 40 CFR 141 (primary MCLs) and 40 CFR 143 (secondary MCLs) apply. The Laboratory maintains six wells and two water-storage tanks for supplying potable water to Laboratory community. In NYS, the SDWA requirements pertaining to the distribution and monitoring of public water supplies are promulgated under Part 5 of the NYS Sanitary Code, which is enforced by the SCDHS as an agent for the NYS Department of Health. These regulations are applicable to any water supply which has at least five service connections or regularly serves at least 25 individuals. The Laboratory supplies water to a population of approximately 3,500 employees and visitors and must, therefore, comply with these regulations. In addition, DOE Order 5400.5, Radiation Protection of the Public and Environment, establishes Derived Concentration Guides (DCGs) for radionuclides not covered by existing federal or state regulations.

The BNL groundwater surveillance program uses wells (which are not utilized for drinking water supply) that are designed to monitor research and support facilities where there is a potential for environmental impact, or in areas where past waste handling practices or accidental spills have already degraded groundwater quality. BNL evaluates the potential impact of radiological and non-radiological levels of contamination by comparing analytical results to NYS and DOE reference levels. Non-radiological data from groundwater samples collected from surveillance wells are usually compared to NYS AWQS (6 NYCRR 703.5). Radiological data are compared to the NYS DWS (for tritium, strontium-90 and gross beta), NYS AWQS (for gross alpha and radium-226/228) and 40 CFR 141/DOE DCGs (for determining the 4 mrem/year dose for other beta/gamma-emitting radionuclides).

3.0 Relativistic Heavy Ion Collider (RHIC) Project

The RHIC facility consists of a the Collider ring which is 12,578 feet (3,835 meters) in circumference, the beam injection system (consisting of the W-, X- and Y-Lines), six experimental halls, and a number of support buildings (Figure 6). The RHIC tunnel was constructed at grade and is covered by earthen shielding which is elevated approximately 30 feet above the grade of Ring Road. A portion of the headwaters for the Peconic River enter and exit the ring by means of culverts located in the northwest and east sections of the RHIC ring.

Within the RHIC facility, there are two areas where radionuclides may be produced in the soils outside of the Collider tunnel from beam loss during operational periods. The first area contains the beam stops which are located at the 10 o'clock portion of the ring, and the second contains the collimators which are located at the 8 o'clock region. Secondary particles created at the internal beam stop and collimator areas have the potential to escape into the soils immediately surrounding those areas. Although considerable effort is taken to design appropriate shielding and other engineering controls into these systems, secondary particles will interact with the Si and O atoms which make up most of the quartz-rich sands and gravels (quartz is predominantly SiO_2) that are native to the BNL site. The types of radionuclides created from interacting secondaries include tritium, beryllium-7, carbon-11, nitrogen-13, oxygen-15, and sodium-22 (Stevens, 1987; BNL, 1991a). Once present in the soils, these radionuclides can be leached downward into groundwater by means of rainwater percolation. These leaching processes are usually quite slow and, therefore, only radionuclides with long half-lives such as tritium ($t_{1/2}$ = 12.3 years) and sodium-22 ($t_{1/2}$ = 2.6 years) are likely to be detected in the groundwater immediately below the zones of production. The production of these isotopes has been measured in experiments using soils native to BNL that were exposed to the AGS beam line (Gollon *et al.*, 1989). Leaching tests conducted on these soils showed the tritium to be 100% leachable whereas sodium-22 is 7.5% leachable.

Similar to the evaluations previously conducted for radionuclide production in soils at the Alternating Gradient Synchrotron (see Beavis *et al.*, 1993), Stevens (1987, 1998a, 1998b) provided estimates on radionuclide production in soil near the RHIC beam stops and collimator areas using the computer code CASIM. In the AGS SAR, Beavis *et al.* (1993) determined the acceptability of radionuclide production in soils by comparing predicted concentrations at a potential source to five times the Design Concentration Guide (DCG) in DOE Order 5400.5. The DCG for a radionuclide is the concentration in water, which if ingested at a rate of two liters per day for one year, would result in a committed effective dose equivalent (CEDE) of 100 mrem. DOE Order 5400.5 requires that liquid effluents from DOE activities shall not cause private or public drinking water systems located downstream of facility discharges to exceed the drinking water radiological limits promulgated in 40 CFR Part 141, National Primary Drinking Water Standards. The drinking water standards set by EPA are based upon a dose of 4 mrem CEDE per year. The DOE Order indicates that the 5 times the DCG value is to be used to evaluate the need to apply Best Available Technology (BAT) to that liquid effluent. This assessment method was used by the RHIC Project and AGS Departments because existing Orders and regulations are designed to address the more common problem of controlling radioactive liquid effluent releases to surface waters (e.g., BNL sanitary discharges), and they do not address the direct activation of soils and resulting contamination of groundwater. By using this method, the only requirement that needs to be satisfied in order to demonstrate environmental compliance is to guarantee that any radionuclides which are produced in soils are reduced to concentration levels which would meet the 4 mrem/yr criteria at the point of ingestion (both on and off-site). Although detailed groundwater modeling has not been performed, it is likely that radionuclides leached from soils near the RHIC beam stops and collimator areas would undergo significant dilution upon entering the water table, and would be further reduced to concentrations either below drinking water standards or non-detectable following dilution and decay in transit to the nearest BNL drinking water supply well, well 10 (BNL, 1991b; Paquette and Schroeder, 1996). The distance between the collimator area and supply well 10 is approximately 3,500 feet or a groundwater travel time of almost 12 years.

Although intended for application to liquid effluents, environmental ALARA considerations should include the assessment of: 1) alternative operating methods and engineering controls; 2) radiological doses under each alternative; 3) the benefits and cost of implementing each alternative; and 4) societal and environmental impacts. To address local stakeholders' desire that the greatest possible effort be made to eliminate intentional releases of radionuclides to the environment, the Laboratory will be taking all reasonable steps to prevent the leaching of these materials to groundwater. Prior to the start of operations with beam at RHIC, the Laboratory will install geomembrane covers over the beam stop and collimator areas as a means of preventing rainwater from leaching through the soils at the source of radionuclide production (Paquette and Schroeder, 1996; Davis, 1996; Stevens 1996b; Stevens, 1997b). With the installation of the caps, it is anticipated that most of the radioactivity produced at the RHIC beam stops and collimators will decay in place. The remediation of any residual activated soils would have to be addressed as a part of any future decommissioning and decontamination (D&D) program for these facilities.

3.1 RHIC Beam Stop Area

<u>Potential Groundwater Vulnerability</u>

The RHIC beam stops are located at the 10 o'clock intersection region of the Collider (Building 1010), and are the place where the vast majority (~85%) of the beam energy will end up (Stevens, 1996a). Consequently, there is concern that direct activation of soils surrounding the RHIC tunnel may impact groundwater quality in areas surrounding the beam stops. The beam stops are located approximately 200 feet to the north and south of the centerline of Building 1010 (Figures 6 and 7). The southern beam stop is located approximately 200 feet north of the culvert that conveys the Peconic River below the RHIC ring.

In an effort to predict radionuclide production at the beam stops, Stevens (1996a, 1998a) evaluated possible tritium and sodium-22 concentrations in soils directly outside the Collider tunnel. Based upon these evaluations, the maximum predicted annual production of tritium and sodium-22 in soils within 40 cm of the tunnel walls and floor is 220 pCi/cc of soil and 270 pCi/cc of soil, respectively. This production rate is obtained assuming four times the design intensity of RHIC, which was considered as the safety envelop limit for the evaluation. Assuming that the geomembrane cap was not installed, a conservative prediction of the possible concentration of tritium and sodium-22 can be made by assuming that approximately half of the total amount of annual precipitation (55 cm of the total of 122 cm annual average) leaches through the most activated of these soils. (The remainder of the precipitation is lost due to evaporation or evapotranspiration.) Under this scenario, the annual average tritium and sodium-22 concentrations in soil pore water directly below the beam dump areas may be as high as 170,000 pCi/l and 20,300 pCi/l, respectively (Stevens, 1998a). However, the volume of water having these high concentrations at each beam stop would likely to be less than 40 gallons annually (Stevens, 1998b), and there would be significant dilution of this water within a short distance upon entering the aquifer system.

To limit the potential impact that the RHIC Project may have on groundwater quality, landfill-type caps (using geomembrane fabric) will be installed over the two beam stop areas prior to the scheduled CY 1999 start operations with beam at RHIC (see Davis, 1996; Stevens, 1996b; Stevens, 1997c). The design goal for these caps is to prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby prevent the leaching of radionuclides to groundwater. By preventing rainwater infiltration through the most significantly impacted soils, Stevens (1998a) predicted that the tritium and sodium-22 pore water concentrations will be reduced by a factor of at least 100, to concentrations in the range of 1,700 pCi/l and 200 pCi/l, respectively.

General Hydrogeology

The predominant groundwater flow direction in the RHIC beam stop area is to the southeast (Figures 4, 5 and 8). The RHIC beam stop area was built in the low lying portion of the Peconic River drainage system. The depth to groundwater below the tunnel floor is approximately 15 feet, whereas in low lying areas off the RHIC berm, near the Peconic River, the depth to groundwater can be as little as five feet or less. Furthermore, recently installed borings at the 9 o'clock portion of RHIC indicate portions of the tunnel may have been constructed over low permeability fine sands, silts and clays that are indicative of stream deposition. These low permeability deposits may retard the percolation of rainwater, which may result in perched or semi-perched water table conditions.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly upgradient or downgradient of the beam stops. Wells that could be used to assess background conditions within the Upper Glacial aquifer are located approximately 1,400 feet upgradient of the beam stop area, at the BNL northern site boundary (e.g., Wells 17-01, 17-02, and 17-03). These wells are used for assessing background (ambient) radionuclide concentrations within the Upper Glacial aquifer. To date, tritium values for these wells have been either non-detectable or slightly above detection limits (which is consistent with world-wide fallout values), and sodium-22 has never been detected.

Proposed Groundwater Monitoring Upgrades

As a means of verifying that the operation of the RHIC beam stops will not impact groundwater quality, BNL will establish a routine groundwater monitoring program for the area (Paquette, 1998). During FY 1999, a total of six new wells will be installed in the beam stop area (Figure 8, Table 2). Two shallow Upper Glacial aquifer wells will be installed directly downgradient of each beam stop (wells MW-RHIC-03 through -06), and one well will also be installed directly upgradient of each beam stop (wells MW-RHIC-01 and -02). The upgradient wells will be installed on top of the bermed area overlying the RHIC tunnel, as close as possible to the upgradient side of each beam stop (within 10 feet). The wells will be screened from five feet above to ten feet below the water table. If perched water table conditions are found in the beam stop area, additional wells will be installed in the perched water table.

The new wells will be monitored by the ES&H Services Division as part of the EM Program (Table 3). Samples will be collected quarterly for gamma spectroscopy and tritium analyses, and semiannually for gross alpha/beta and metals. Furthermore, because the southern beam stop is located within 200 feet of the culvert for the Peconic River, surface water samples will be collected to verify that potentially activated groundwater is not being discharged to the stream bed during high transient water table conditions. When surface water is present, water samples will be collected at a sample location near the Ring Road on a quarterly basis for tritium analysis and gamma spectroscopy. Data from the new wells near the beam stops will be compared to results from existing well 17-01, a shallow BNL site perimeter well which is currently monitored quarterly as part of the ER Program. The monitoring program will begin prior to the start-up of the RHIC in order to fulfill DOE pre-operational environmental surveillance requirements.

3.2 RHIC Collimator Areas

Potential Groundwater Vulnerability

The RHIC limiting aperture collimators are identified areas of beam loss, and are therefore of concern with regard to potential activation of soils. The collimator areas are located at the 8 o'clock region of the RHIC (Figures 6 and 7). In these areas, tritium and sodium-22 may be produced in the soils directly outside the Collider tunnel (Stevens, 1997a; Stevens, 1997b; Stevens, 1998a). In the collimator area, the maximum tritium and sodium-22 concentrations are expected to be approximately five times less than those predicted for the RHIC beam stop area. In soils within 40 cm of the tunnel walls and floors near the collimators, Stevens (1997a, 1997b, 1998a) estimated that tritium and sodium-22 concentrations will be 50 pCi/cc of soil and 61 pCi/cc of soil, respectively. Assuming that the gromembrane cap was not installed, a conservative prediction of the possible concentrations of tritium and sodium-22 in leachate can be made by assuming that approximately half of the total amount of annual precipitation (55 cm of the total of 122 cm annual average) leaches through the most activated soils. Under this scenario, the annual average tritium and sodium-22 concentrations in pore water directly below the collimator areas may be as high as 39,000 pCi/l and 4,600 pCi/l, respectively (Stevens 1998a). It should be noted that the volume of water having these high concentrations would be less than 120 gallons annually along the length of the collimator area (Stevens, 1998b), and that there would be significant dilution of this water within a short distance upon entering the aquifer system.

In an effort to reduce the potential impact that the RHIC Project may have on groundwater quality, a landfill-type cap (using geomembrane liners) will be constructed over the collimator areas prior to the scheduled CY 1999 start of beam operations at RHIC (see Davis, 1996; Stevens, 1996b; Stevens 1997a; Stevens 1997c). The caps will prevent the infiltration of precipitation through the most highly activated soils surrounding the tunnel, and thereby limiting the leaching of radionuclides to groundwater. By preventing surface water from infiltration through the most heavily impacted soils, it is predicted that the tritium and sodium-22 concentrations in soil pore water will be reduced by a factor of at least 100, with concentrations on the order of 400 pCi/l and 46 pCi/l, respectively (Stevens, 1998a).

General Hydrogeology

The predominant groundwater flow direction in the RHIC collimator area is to the southeast, which is parallel to the RHIC tunnel in this region (Figures 4, 5, and 8). The depth to groundwater below the tunnel floor is approximately 15 feet. In areas off the main RHIC berm, the depth to groundwater ranges between 10 to 20 feet. Current information indicates that the collimator area is underlain by predominantly medium to coarse grained sands and gravel.

Current Groundwater Monitoring Program

Presently, there are no groundwater monitoring wells located directly downgradient of the RHIC collimator areas. Wells are located upgradient of the RHIC, at the BNL northern site boundary (e.g., Wells 17-01, 17-02, 17-03 and 25-01). These wells are used for assessing background (ambient) radionuclide concentrations within the Upper Glacial aquifer. To date, tritium values for these wells have been either non-detectable or slightly above detection limits (which is consistent with world-wide fall-out levels), and sodium-22 has never been detected.

Proposed Groundwater Monitoring Upgrades

As a means of verifying that the operations at the RHIC collimator areas will not impact groundwater quality, BNL will establish a routine groundwater monitoring program during FY 1999 (Paquette, 1998). The groundwater monitoring program will require a minimum of six new monitoring wells (Figure 8, Table 3). Four wells (MW-RHIC-09 through -12) will be installed directly downgradient of the collimator portion of the tunnel. Because the direction of groundwater flow is nearly parallel with this portion of the RHIC tunnel, the wells will be installed close to the tunnel on both the east and west sides. The downgradient wells will be installed as couplets, with shallow wells screened from five feet above to ten feet below the water table, and deeper wells screened from 15 to 25 feet below the water table. In an effort to establish a more direct means of evaluating groundwater quality close to the potentially activated soils, two wells (MW-RHIC-07 and -08) will be installed along the top of the RHIC tunnel, approximately 150 feet to the north and south of beam crossing point located within Building 1008. The wells will be positioned adjacent to the front edge of the collimators, where the predicted highest levels of soil activity will occur (Stevens, 1997a).

The wells will be monitored on a quarterly basis by the ES&H Services Division as part of the EM Program for facility surveillance (Table 3). Groundwater samples will collected on a quarterly basis for tritium and gamma spectroscopy, and semiannually for gross alpha/beta and metals. Assessment of background radionuclide concentrations will be accomplished utilizing existing Upper Glacial aquifer wells 17-01 and 25-01. Well 17-01 is presently monitored quarterly as part of the ER Program, and the monitoring of well 25-01 will be conducted as part of the EM Program. The monitoring program will begin prior to the start-up of the RHIC in order to fulfill DOE pre-operational environmental surveillance requirements.

4.0 Well Installation Methods

The groundwater monitoring wells installed as part of this plan shall be constructed in accordance with the BNL "Technical Guide for the Installation of Monitoring Wells and Piezometers" (BNL, 1996). This specification is consistent with the well installation guidelines required by the USEPA and the NYSDEC for both CERCLA and RCRA groundwater investigations. Since the wells installed under this plan will be located in close proximity to a suspected source areas, the wells will be screened across the water table. Recent data collected during detailed tritium plume investigations at the BNL

HFBR and BLIP facilities indicate that the highest tritium levels will occur close to the water table in wells located directly downgradient of the source area. The short distance traveled and lack of density differences between tritium and fresh water are the likely cause.

Once installed the wells will be surveyed by a N.Y. State licensed surveyor from the BNL Plant Engineering Division to determine their vertical and horizontal positions. All new wells will be surveyed, using the BNL bench mark control system, to a horizontal accuracy of 0.50 feet and to a vertical accuracy of 0.01 feet.

5.0 Sample Collection and Analysis

All permanent groundwater monitoring wells installed for the EM program will be sampled by the BNL ES&H Services Division using Standard Operating Procedure EM-SOP-25. Each new well will be completed with a new dedicated Geoguard® bladder purge pump (Master-Flo Model 57200M - constructed of NSF rated PVC and Teflon®). Dedicated pumping systems eliminate the need to decontaminate pumps between well sampling events, and prevent potential cross contamination problems if the same pump is used in multiple wells.

The wells will be sampled in accordance with the schedule presented in Table 5. All gross alpha and beta (Method 900), gamma spectroscopy (Method 901.1), and tritium analyses (Method 906) will be performed by the ES&H Services Division's Analytical Services Laboratory (ASL).

The ASL is certified by the New York State Department of Health Services for each of the analyses performed. The ASL also participates in the DOE Environmental Measurements Laboratory (EML) QA Program and the EPA National Exposure Research Laboratory Performance Evaluation Study. All contractor labs used for groundwater analyses are also NYSDOH certified. The BNL ASL and contractor labs have established standard operating procedures to calibrate instruments, analyze samples, and check quality control. Depending upon the analytical method, quality control checks include the analysis of blanks or background concentrations, use of Amersham or National Institute for Standards and Technology (NIST) traceable standards, and analysis of reference standards, spiked samples, and duplicate samples. All analytical results are reviewed by BNL ASL supervisors for completeness and accuracy. Quality assurance procedures for the EM Program are described in detail by Schroeder *et al.* (1998).

5.1 Data Quality Objectives

Data Quality Objectives (DQOs) are the statements specifying the quality of data needed to support decisions relative to various stages of environmental surveillance or remedial actions. They are based upon the concept that different data uses require different levels of data quality with respect to the precision, accuracy, and completeness of the data. DQOs must be in place to ensure that the data obtained from the groundwater monitoring program are of sufficient quality, are scientifically defensible, and have the requisite levels of precision and accuracy to support any decisions regarding the assessment of potential impacts of facility operations on groundwater quality. The US EPA (1994) developed a six step DQO evaluation process which is intended to clarify monitoring program objectives, define data needs, and determine data precision and tolerance levels to support decision making. The seven steps are: 1) describe the problem to be studied; 2) identify the decision by determining questions to be answered and actions that may result; 3) identify the data inputs to the decision; 4) define study boundaries; 5) develop a decision rule that describes the logical basis for choosing alternative actions; 6) specify tolerable limits on decision errors; and 7) optimize the data collection process design by evaluating information gathered during steps 1 through 6. Although the information and proposed groundwater monitoring improvements provided above satisfy a number of these DQO steps, a more rigorous review must be performed to establish appropriate decision rules and decision errors for the RHIC groundwater surveillance program.

As noted above, all sample analyses are performed using standardized US EPA methods, and all data generated as part of the EM Program have full quality control documentation and data validation conducted by BNL and/or contractor personnel using standardized USEPA protocols. Quality assurance procedures for the EM Program are described in detail by Schroeder *et al.* (1998).

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Table 1
BNL RHIC Facility - Potential Impacts to Groundwater Quality
Selected Hydrogeologic Units of Long Island

<table>
<tr><th>System</th><th colspan="2">Geologic unit</th><th>Hydrogeologic unit</th></tr>
<tr><td rowspan="3">Quaternary</td><td colspan="2">Holocene (Recent) deposits</td><td rowspan="2">Upper glacial aquifer</td></tr>
<tr><td colspan="2">Upper Pleistocene deposits including "unidentified" unit</td></tr>
<tr><td colspan="2">Gardiners Clay</td><td>Gardiners Clay</td></tr>
<tr><td rowspan="4">Cretaceous</td><td colspan="2">Monmouth Group</td><td>Monmouth greensand</td></tr>
<tr><td colspan="2">Matawan Group-Magothy Formation, undifferentiated</td><td>Magothy aquifer</td></tr>
<tr><td rowspan="2">Raritan Formation</td><td>unnamed clay member</td><td>Raritan confining unit</td></tr>
<tr><td>Lloyd Sand Member</td><td>Lloyd aquifer</td></tr>
<tr><td>Precambrian</td><td colspan="2">Bedrock</td><td>Relatively impermeable bedrock</td></tr>
</table>

From Scorca *et al.* (1996)

Brookhaven National Laboratory
Relativistic Heavy Ion Collider - Potential Impacts to Groundwater Quality
Proposed Groundwater Monitoring Wells for FY 1999
Table 2

Well	Area	Land Surface (MSL)	Water Table (MSL)	Screen Interval (BLS)	Total Depth (BGS)
MW-RHIC-01	RHIC-Beam Stop (U*)	90'	47'	38'-53'	58'
MW-RHIC-02	RHIC-Beam Stop (U*)	90'	47'	38'-53'	58'
MW-RHIC-03	RHIC-Beam Stop (D)	60'	47'	8'-23'	28'
MW-RHIC-04	RHIC-Beam Stop (D)	60'	47'	8'-23'	28'
MW-RHIC-05	RHIC-Beam Stop (D)	60'	47'	8'-23'	28'
MW-RHIC-06	RHIC-Beam Stop (D)	60'	47'	8'-23'	28'
MW-RHIC-07	RHIC Collimator (U*)	90'	47'	38'-53'	58'
MW-RHIC-08	RHIC Collimator (U*)	90'	47'	38'-53'	58'
MW-RHIC-09	RHIC Collimator(D)	90'	47'	38'-53'	58'
MW-RHIC-10	RHIC Collimator(D)	90'	47'	63'-73'	78'
MW-RHIC-11	RHIC Collimator(D)	80'	47'	28'-43'	48'
MW-RHIC-12	RHIC Collimator(D)	80'	47'	53'-63'	68'

U = Upgradient Well D = Downgradient Well MSL = Feet Relative to Mean Sea Level BLS = Below Land Surface

Brookhaven National Laboratory
Proposed RHIC Groundwater Sampling Schedule for CY 1998 and CY 1999

Table 3

RHIC Facility

<u>Wells:</u> 25-01, MW-RHIC-01, MW-RHIC-02, MW-RHIC-03, MW-RHIC-04, MW-RHIC-05, MW-RHIC-06, MW-RHIC-07, MW-RHIC-08, MW-RHIC-09, MW-RHIC-10, MW-RHIC-11, MW-RHIC-12.

Contaminants of Concern
Tritium, Sodium-22

Sample Periods for CY 1998
November
Sample Periods for CY 1999
February, May, August, November

Sample Period CY 1999 **Laboratory**	1st Qtr. ES&H	2nd Qtr. ES&H	3rd Qtr. ES&H	4th Qtr. ES&H
Analysis				
VOCs				
(EPA 624)				
Semi-VOCs				
(EPA 625)				
Pesticides/PCBs				
(EPA 608)				
Metals				
(EPA 200 Series)		X		X
Radionuclides				
Tritium(EPA 906)	X	X	X	X
Strontium-90 (EPA 905)				
Gross alpha/beta (EPA 900)	X		X	
Gamma (EPA 901.1)	X	X	X	X
Anions - Water Quality				
(EPA 300)	X			
pH and conductivity	X	X	X	X

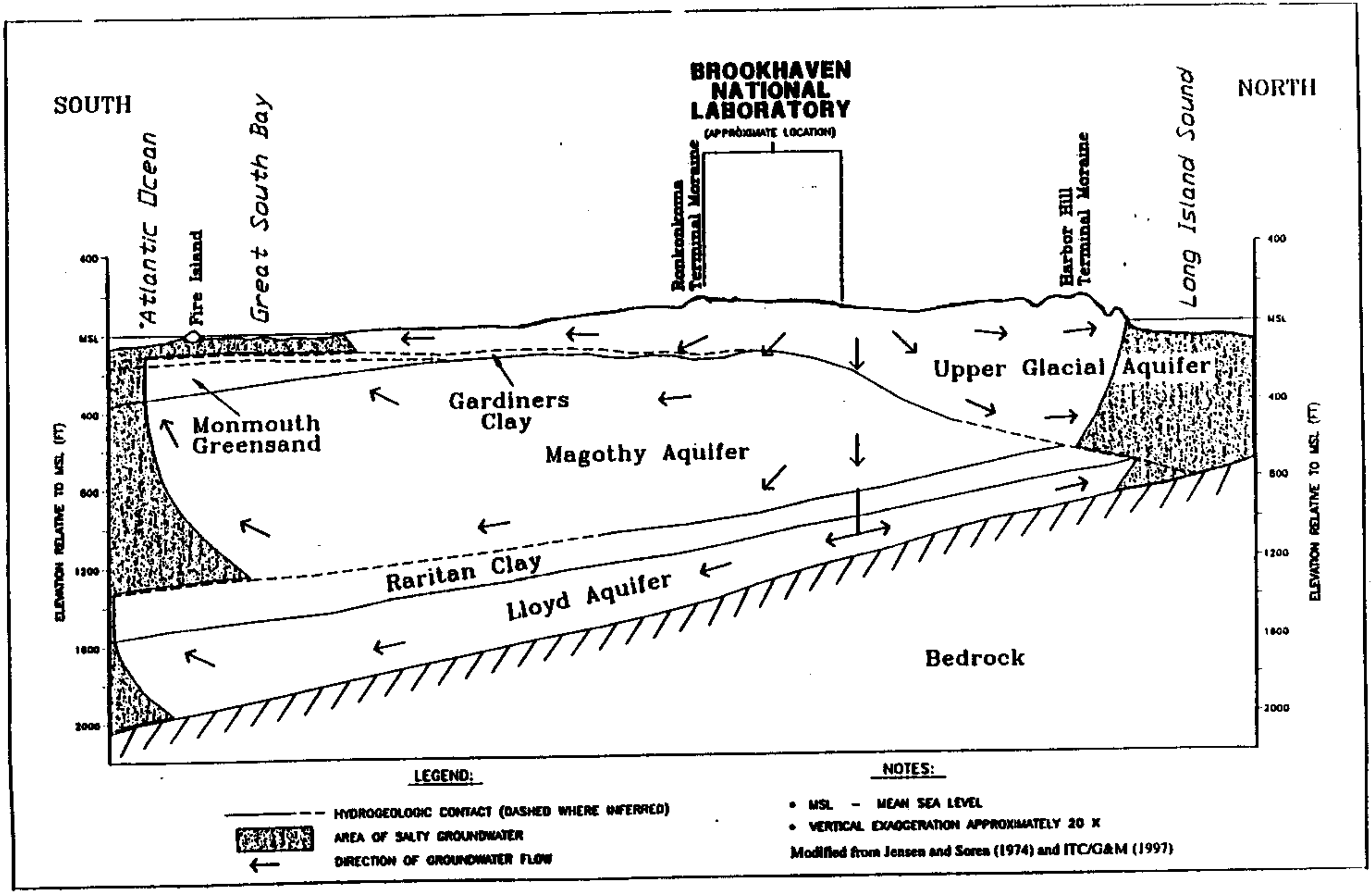
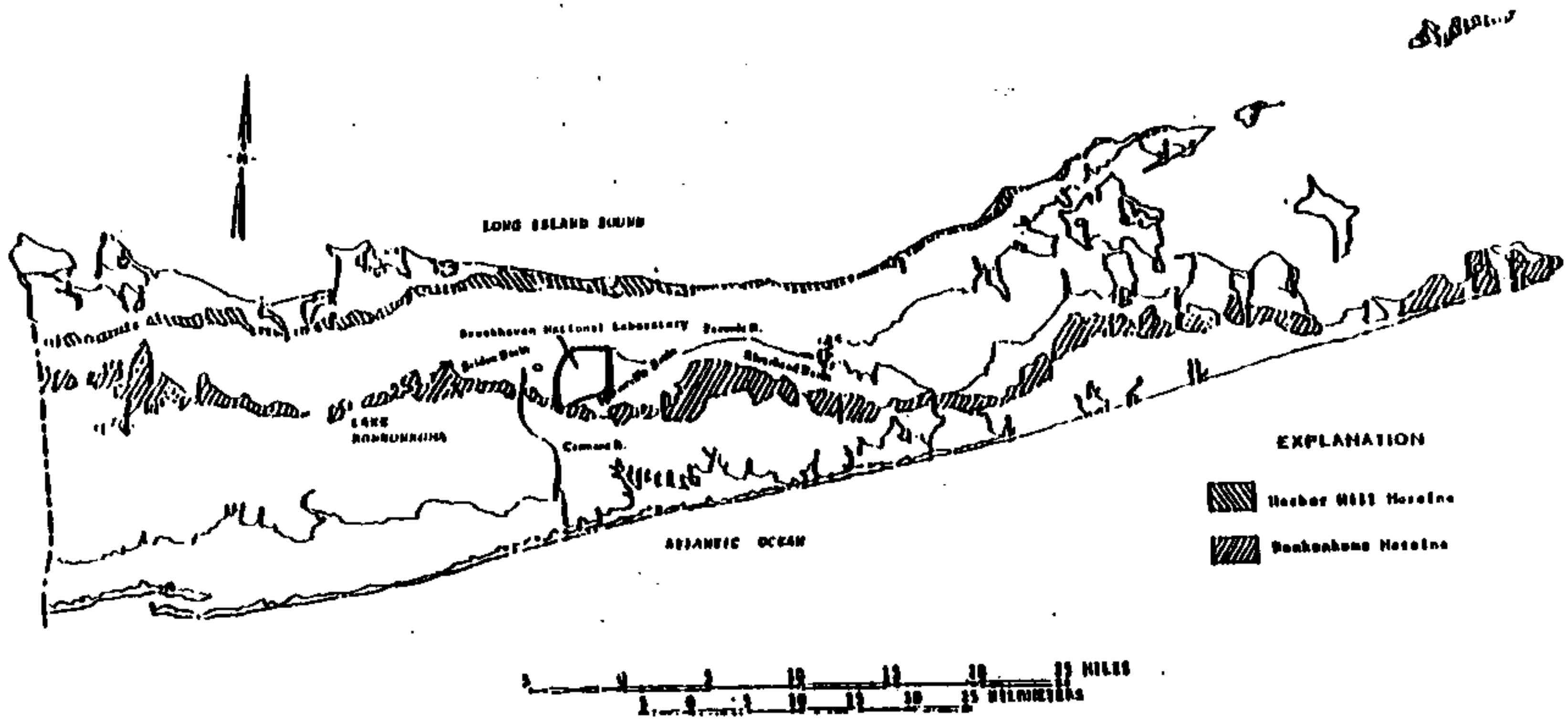
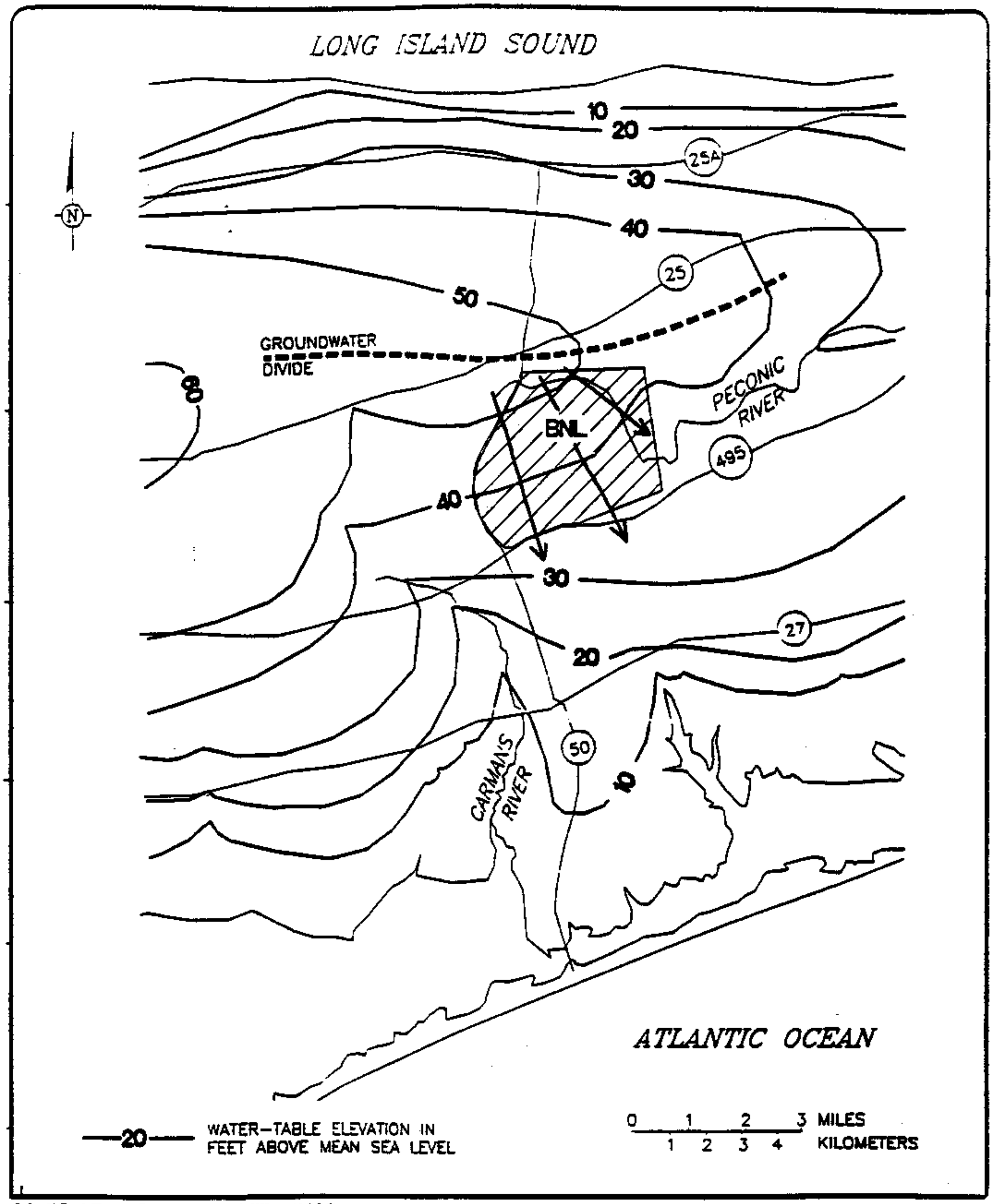


Figure 1
BNL RHIC Facility - Potential Impacts to Groundwater Quality
Generalized Hydrogeologic Cross Section of Long Island, New York



Geology adapted from deLaguna (1963), and Jensen and Soren (1974)

Figure 2
BNL RHIC Facility - Potential Impacts to Groundwater Quality
Locations of Glacial Moraines and Basins, Suffolk County, New York



Modified From Geraghty and Miller (1996)

Figure 3
BNL RHIC Facility - Potential Impacts to Groundwater Quality
Generalized Regional Water Table Configuration Map

Figure 4
BNL RHIC Facility - Potential Impacts to Groundwater Quality
BNL Site Water Table Map for March 1997

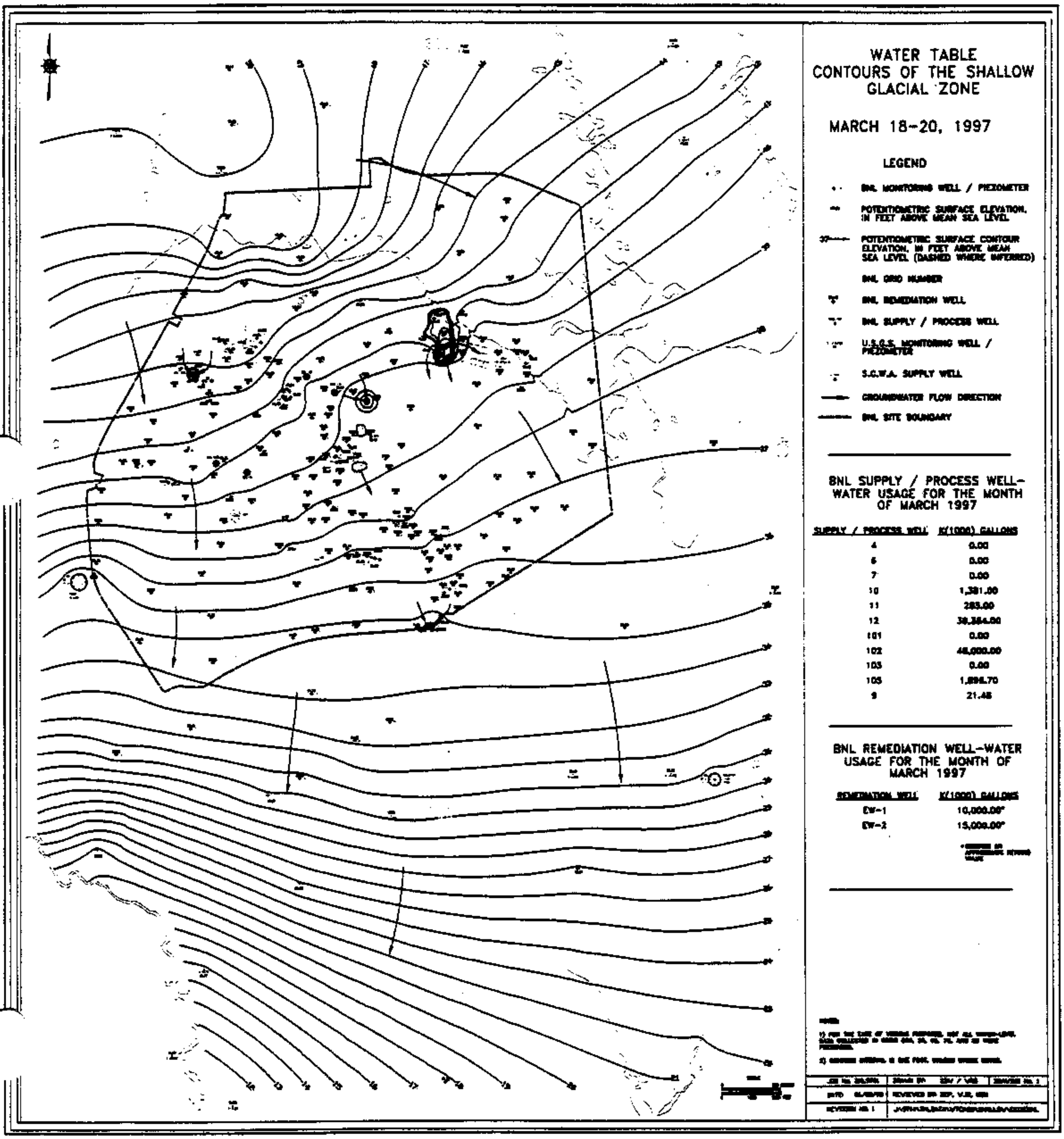
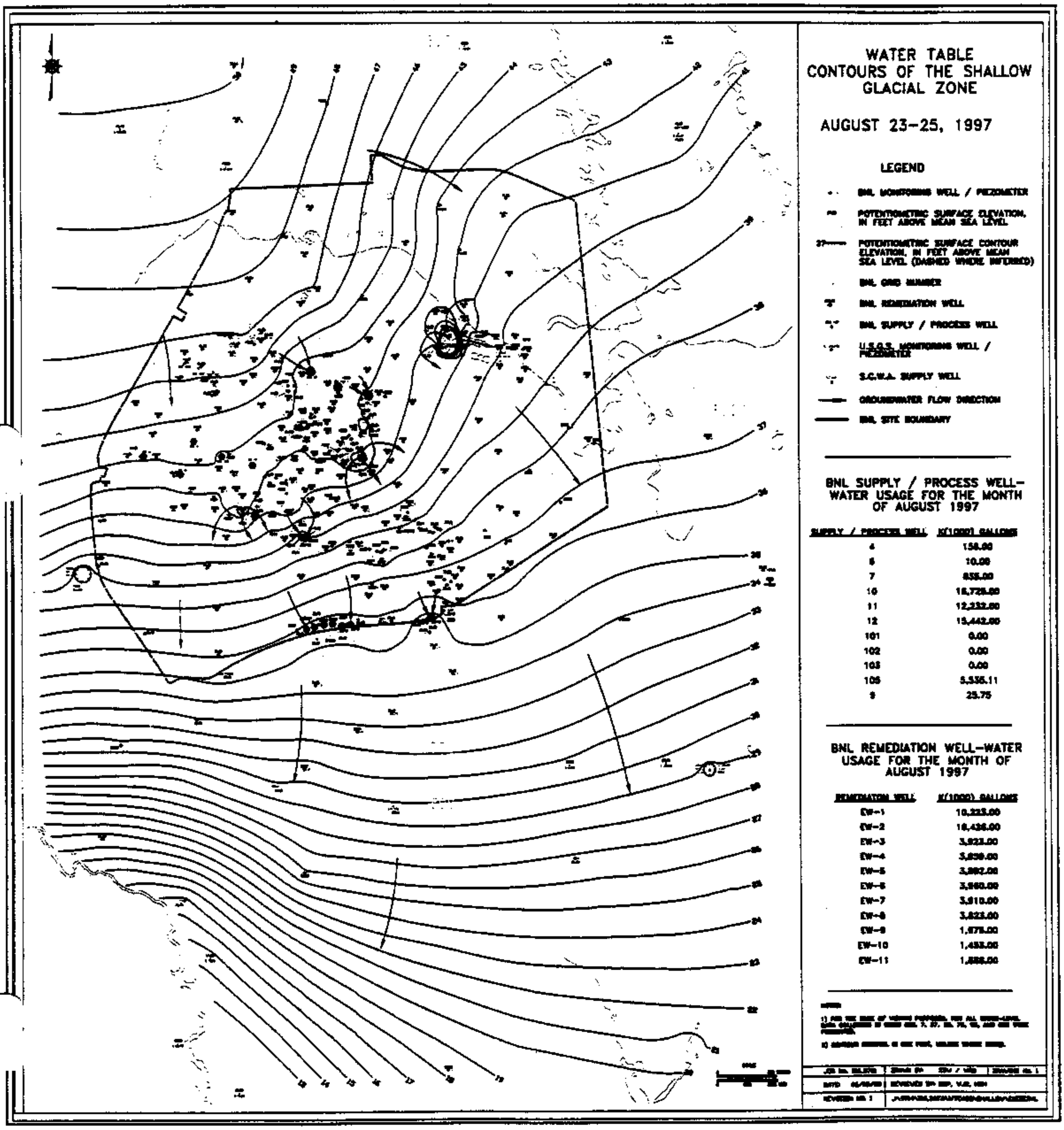


Figure 5
BNL RHIC Facility - Potential Impacts to Groundwater Quality
BNL Site Water Table Map for August 1997



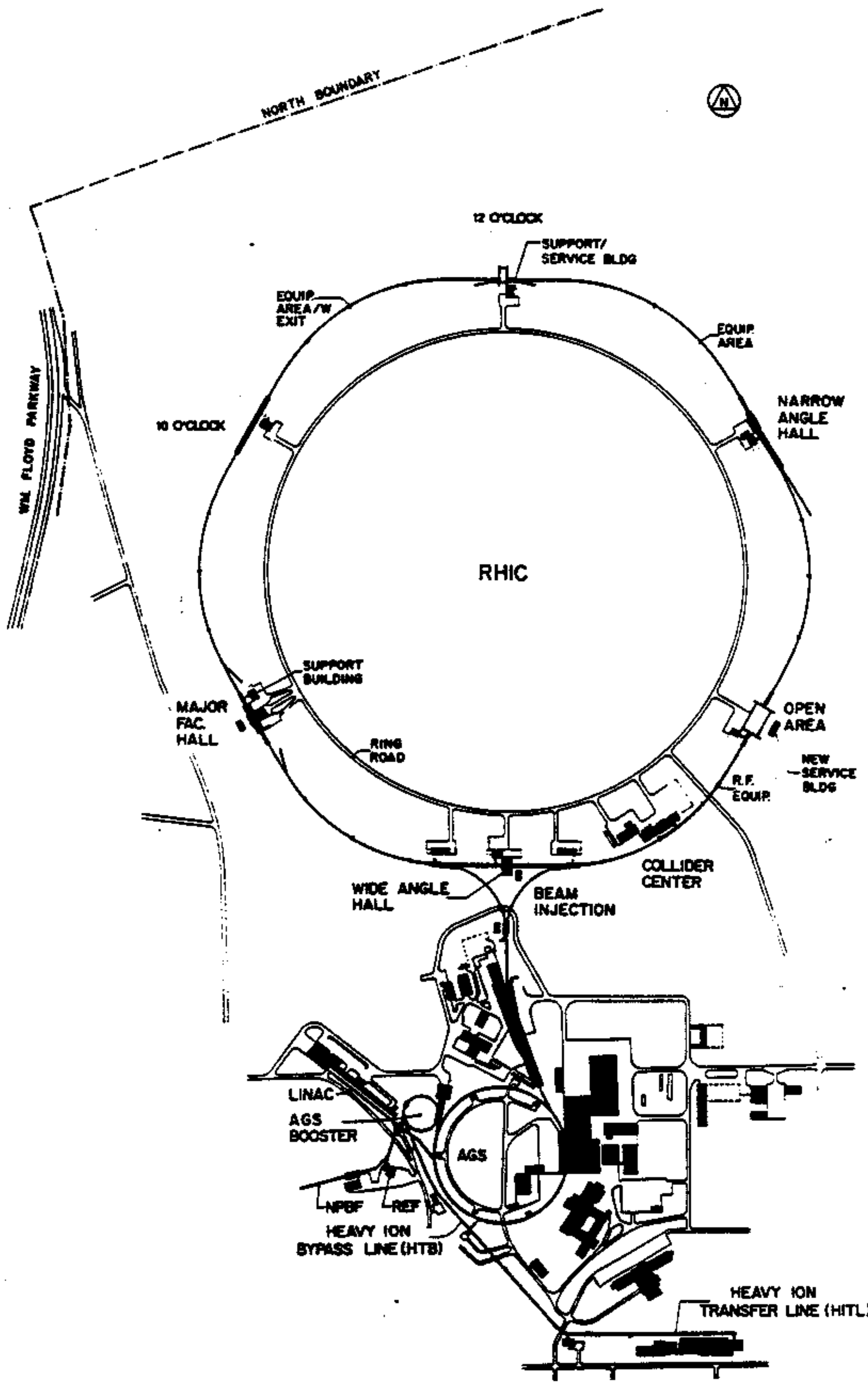


Figure 6
BNL RHIC Facility - Potential Impacts to Groundwater Quality
BNL Site Map Showing AGS and RHIC Facilities

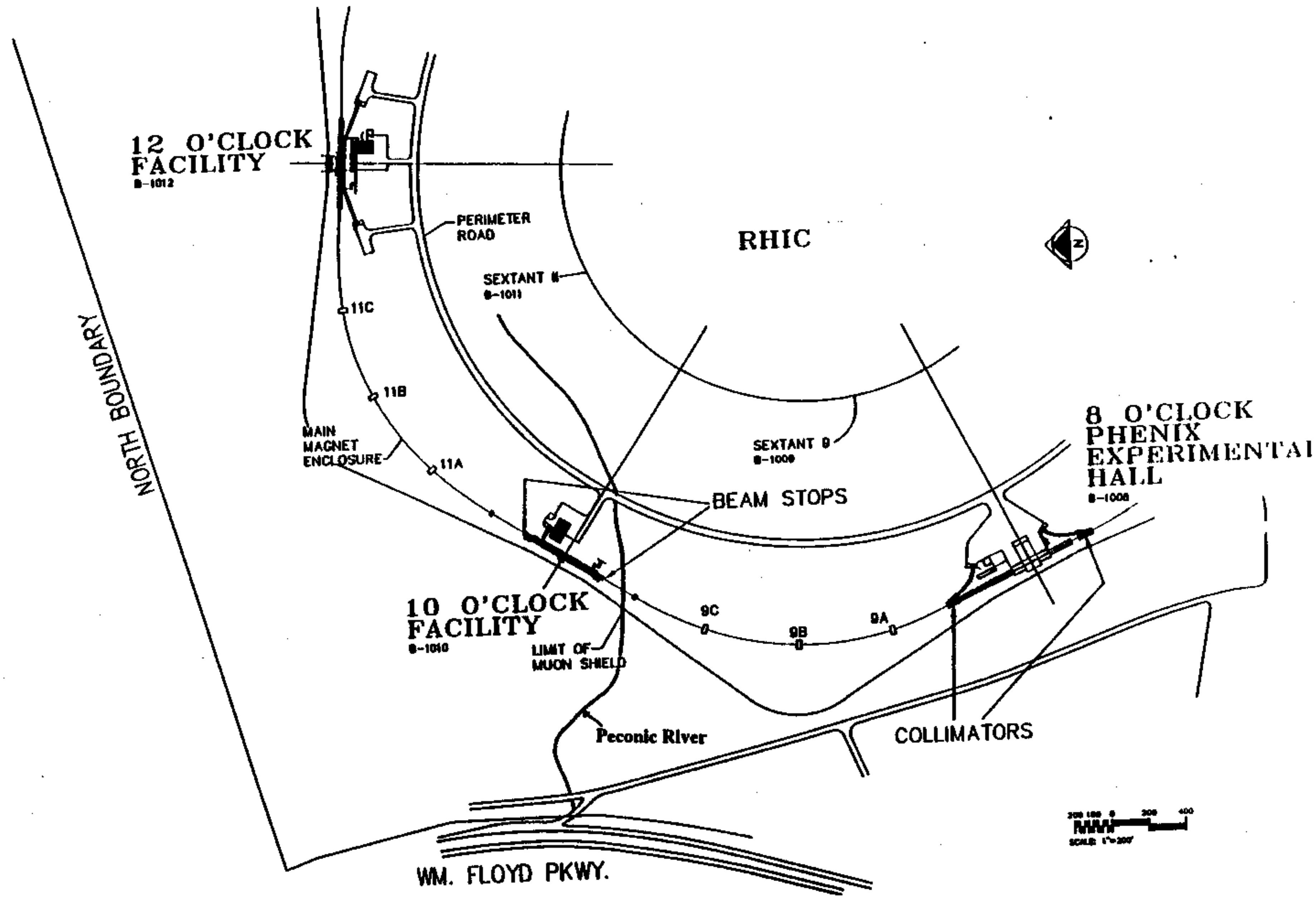


Figure 7
BNL RHIC Facility - Potential Impacts to Groundwater Quality
RHIC Beam Stop and Collimator Areas

Figure 8

Relativistic Heavy Ion Collider Facility
Proposed Well Locations